BMT Fleet Technology Limited

TP 14176E

Decelerometer Tests: CRFI Quality Assurance Tests and the Effect of the Vehicle's ABS System

Prepared for
Transportation Development Centre
On behalf of
Aerodrome Safety Branch of Civil Aviation
Transport Canada
December 2003

104-03460/

TP 14176E

Decelerometer Tests: CRFI Quality Assurance Tests and the Effect of the Vehicle's ABS System

Prepared for
Transportation Development Centre
On behalf of
Aerodrome Safety Branch of Civil Aviation
Transport Canada
December 2003

by
BMT Fleet Technology Limited
311 Legget Drive
Kanata, ON
K2K 1Z8

TP 14176E

Decelerometer Tests: CRFI Quality Assurance Tests and the Effect of the Vehicle's ABS System

by
G. Comfort and S. Verbit
BMT Fleet Technology Limited

December 2003

DISCLAIMER

The views expressed in this report are those of BMT Fleet Technology Limited and are not necessarily representative of those of Transport Canada.

BMT Fleet Technology Limited does not endorse any of the products or manufacturers named in this report. Trade names or manufacturers' names appear only because they are required to document the study described in this report.

Since some of the accepted measures in the industry are imperial, metric measures are not always used in this report.

PROJECT TEAM

BMT Fleet Technology Limited	
George Comfort	Project Manager and Principal Investigator
Stephanie Verbit	Project Engineer, CRFI Assurance Tests
Almar Consulting	
Al Mazur	Principal Investigator and Overall Review
Tradewind Scientific Ltd	
Leonard Taylor	Planning and execution of ABS System Field Tests
Transport Canada	
Angelo Boccanfuso	Project Officer, Transportation Development Centre
Dominic Morra	Project Officer, Aerodrome Safety

Un sommaire français se trouve avant la table des matières.

Transport Canada Transports Canada

PUBLICATION DATA FORM

1. Transport Canada Publication No. TP 14176E	2. Project No. 5332	3. Recipient's Catalogue No.

4. Title and Subtitle Decelerometer Tests: CRFI Quality Assurance Tests and the Effect of the Vehicle's ABS System	5. Publication Date December 2003 6. Performing Organization Document No.
7. Author(s) G. Comfort and S. Verbit	8. Transport Canada File No. 2450-BP14
9. Performing Organization Name and Address BMT Fleet Technology Limited 311 Legget Drive Kanata, Ontario K2K 1Z8	10. PWGSC File No. 11. PWGSC or Transport Canada Contract No.
12. Sponsoring Agency Name and Address Transportation Development Centre (TDC) 800 René Lévesque Blvd. West Suite 600 Montreal, Quebec H3B 1X9	13. Type of Publication and Period Covered Final 14. Project Officer Angelo Boccanfuso

15. Supplementary Notes (Funding programs, titles of related publications, etc.)

16. Abstract

This is a two-part project to investigate the friction coefficients measured by decelerometers at Canadian airports, comprised of: (a) Canadian Runway Friction Index (CRFI) Quality Assurance Tests and, (b) Antilock Braking System (ABS) Effect tests.

CRFI Quality Assurance Tests were done to compare the CRFIs obtained with decelerometer systems in use at different airports with the Transport Canada (TC) system that consisted of (a) the TC Blazer, (b) an ERD Mk II, and (c) D. Booth, of North Bay airport, who operated the Blazer. Tests were conducted at five airports in northern Ontario during two periods in January and February 2003. Tests were done on operational surfaces that covered a range of friction levels, rather than prepared surfaces, at the airports. Tests were also done with the operators switched.

ABS Effect Tests were done to measure the degree to which CRFIs are affected by whether or not the vehicle's ABS is on or off. The tests extended the database obtained during a similar test program conducted in 2002 by evaluating: (a) a wider range of vehicles; (b) several decelerometer types; and, (c) a wider range of surfaces.

17. Key Words CRFI, decelerometer, friction	18. Distribution Statement Limited number of copies available from the Transportation Development Centre

19. Security Classification (of this publication) Unclassified	20. Security Classification (of this page) Unclassified	21. Declassification (date) —	22. No. of Pages xx, 72, apps	23. Price Shipping/ Handling

Transports Canada Transport Canada

FORMULE DE DONNÉES POUR PUBLICATION

1. Nº de la publication de Transports Canada
TP 14176E

2. Nº de l'étude
5332

3. Nº de catalogue du destinataire

4. Titre et sous-titre
Decelerometer Tests: CRFI Quality Assurance Tests and the Effect of the Vehicle's ABS System

5. Date de la publication
Décembre 2003

6. Nº de document de l'organisme exécutant

7. Auteur(s)
G. Comfort et S. Verbit

8. Nº de dossier - Transports Canada
2450-BP14

9. Nom et adresse de l'organisme exécutant
BMT Fleet Technology Limited
311 Legget Drive
Kanata, Ontario
K2K 1Z8

10. Nº de dossier - TPSGC

11. Nº de contrat - TPSGC ou Transports Canada

12. Nom et adresse de l'organisme parrain
Centre de développement des transports (CDT)
800, boul. René-Lévesque Ouest
Bureau 600
Montréal (Québec)
H3B 1X9

13. Genre de publication et période visée
Final

14. Agent de projet
Angelo Boccanfuao

15. Remarques additionnelles (programmes de financement, titres de publications connexes, etc.)

16. Résumé

Le présent projet porte sur les coefficients de frottement mesurés à l'aide de décéléromètres à des aéroports canadiens. Il comprend deux volets : (a) essais d'assurance de la qualité du Coefficient canadien de frottement sur piste (CRFI, pour *Canadian Runway Friction Index*) et (b) essais sur l'effet du système de freinage antiblocage (ABS).

Les essais d'assurance de la qualité du coefficient CRFI avaient pour but de comparer les coefficients CRFI obtenus avec les décéléromètres en usage aux différents aéroports avec le système de Transports Canada (TC), constitué de (a) le Blazer de TC, (b) un décéléromètre d'enregistrement électronique (ERD) Mk II et (c) D. Booth, de l'aéroport de North Bay, au volant du Blazer. Les essais ont eu lieu à cinq aéroports du nord de l'Ontario et se sont étalés sur deux périodes, en janvier et février 2003. Ils se sont déroulés sur des surfaces opérationnelles présentant divers coefficients de frottement, plutôt que sur des surfaces préparées expressément pour les essais. En outre, les conducteurs étaient appelés à s'échanger les véhicules.

Les essais sur l'effet de l'ABS visaient à mesurer jusqu'à quel point le fait que le système ABS soit actionné ou non influe sur le coefficient CRFI. Ces essais ont permis d'enrichir la base de données constituée à la faveur d'un programme d'essais semblable mené en 2002; ils ont en effet permis d'évaluer : (a) un éventail plus large de véhicules; (b) plusieurs types de décéléromètres et (c) une gamme plus étendue de surfaces.

17. Mots clés
CRFI, décéléromètre, frottement

18. Diffusion
Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

19. Classification de sécurité (de cette publication)	20. Classification de sécurité (de cette page)	21. Déclassification (date)	22. Nombre de pages	23. Prix
Non classifiée	Non classifiée	—	xx, 72, ann.	Port et manutention

Canada

ACKNOWLEDGEMENTS

The project was monitored by Angelo Boccanfuso of the Transportation Development Centre, Transport Canada.

Dominic Morra of the Aerodrome Safety Branch of Transport Canada provided technical input. The Aerodrome Safety Branch is thanked for supplying many of the decelerometers used in this project: an ERD Mk II, an ERD Mk III, a Tapley, and a Bowmonk.

Al Cormier of Bowmonk is thanked for providing the next generation Bowmonk device used in the ABS tests. He was onsite for part of the ABS tests conducted at North Bay airport.

North Bay Jack Garland Airport is thanked for providing the airport runway and for preparing the winter surfaces (i.e., ice, sanded ice, packed snow, and sanded packed snow) that were used for the ABS test program. Dan Booth, of North Bay Airport, is thanked for participating as the reference operator for the circuit testing, and operating the vehicles during the ABS test program.

Tests were done at the airports listed below. These airports are thanked for the excellent support and cooperation they provided to the project:

- Great Sudbury (Don Dunlop)
- Kapuskasing (Rock Robitaille)
- North Bay Jack Garland (Hector Gauthier)
- Sault Ste. Marie (Don Vallée)
- Timmins (Ivan Perreault and Harley Nikkel)

These airports provided:

- access to the airfield and cooperation;
- site vehicle, decelerometer, and operator for CRFI measurements; and
- assistance (i.e., maintenance garage facilities and personnel) in documenting the vehicles.

EXECUTIVE SUMMARY

This was a two-part project to investigate the friction coefficients measured by decelerometers at Canadian airports, comprised of: (a) Canadian Runway Friction Index (CRFI) Quality Assurance Tests and (b) Antilock Braking System (ABS) Effect tests.

CRFI Quality Assurance Tests – These tests were done to compare the CRFIs obtained with decelerometer systems in use at different airports with the Transport Canada (TC) system. The test vehicles consisted of (a) the TC Blazer, and (b) an Electronic Recording Decelerometer (ERD) Mk II. D. Booth, of North Bay airport, operated the Blazer. The Transport Canada system has been used throughout the Joint Winter Runway Friction Measurement Program (JWRFMP), which commenced in 1996. Tests were conducted at five airports in northern Ontario during two periods in January and February 2003. CRFIs were obtained with the Transport Canada system and the sites' vehicles on the same surface. Tests were done on operational surfaces, rather than prepared surfaces, at the airports. The surfaces covered a range of friction levels. Tests were also done with the operators switched.

The findings were as follows:

- The CRFI variations between the airport systems and the Transport Canada system varied with airport and Circuit. As expected, more small landing distance variations were observed than large ones. Seventy percent of the inferred landing distances for these cases varied by less than 500 ft. The maximum variation in inferred landing distance was 826 ft. (Note that all references made to inferred landing distances apply to an unfactored landing distance of 3000 ft., and to no reverse thrust.)
- Generally, greater variation was observed between the Transport Canada and airport systems for sites that used the ERD Mk III as part of their system.
- In all cases, similar results were obtained with Transport Canada and site operators. The average CRFI variation was 0.013, with a maximum variation of 0.04. This probably indicates that the operators had all been trained to employ similar measurement techniques. It was concluded that switching the operators did not affect the CRFI readings significantly, compared to the other differences seen between vehicle-decelerometer pairs.
- Instrumentation problems were encountered with the ERDs used in the TC system that limited the strength of the conclusions that can be drawn.

Further investigation is recommended regarding: (a) the stability of the standard used as the basis of comparison for this project; (b) decelerometer calibration and certification; (c) decelerometer acceptance and regulation; and (d) the significance of the observed CRFI variations.

ABS Effect Tests – The tests were done to measure the degree to which CRFIs are affected by whether or not the vehicle's ABS is on or off. The tests were aimed at expanding the database obtained during a similar test program conducted in 2002. The 2003 testing evaluated this for: (a) a wider range of vehicles; (b) several decelerometer types; and (c) a wider range of surfaces.

The findings from the whole data set were as follows:

- The effect of ABS on versus off depended on the specific vehicle, decelerometer, and surface under consideration. No universal relationships were apparent, although trends were evident for each vehicle. The effect of ABS on versus off ranged from: (i) increasing the respective friction coefficient to; (ii) decreasing the respective friction coefficient to; and (iii) no effect. Substantial CRFI variations were measured in some cases, depending upon whether or not the vehicle's ABS was on or off.
- the observed friction coefficient variations were examined with respect to their effect on inferred landing distances to evaluate their significance. (Note that all references made to inferred landing distances apply to an unfactored landing distance of 3000 ft., and to no reverse thrust). The largest variations were observed for the ½-ton and the ¾-ton (Table 1) on February 24 during tests done with 6 mm (1/4 in.) of loose snow on bare pavement. Data were only obtained with the ERD Mk III and the ERD Mk II on that day. The Tapley and Bowmonk were not tested on that day as they were not available.

Table 1: Maximum Variation in Inferred Landing Distances for ABS On vs. Off

	ERD MK III	ERD Mk II	Tapley	Bowmonk Peak	Bowmonk Averag
Blazer	- 549	- 533	-171	-106	-695
½-Ton	876	829	-152	-448	614
¾-Ton	924	853	41	220	no data
1-Ton	-202	-334	no data	no data	-116
RWD Car	-302	-310	-189	-256	no data
FWD Car	257	258	34	-427	no data

Notes:

1. The above differences in inferred LD are measured in ft.
2. Negative and positive variations indicate that the inferred LD based on the friction coefficient measured with the ABS off was shorter or longer, respectively.

The above maxima are larger than those observed during the 2002 tests, which was 449 ft. This variation may be due to differences in surface conditions as no tests were done in 2002 on loose snow on pavement. The 2002 tests were all done on bare ice and compacted snow.

The recommended actions depend upon whether or not the above variations in inferred landing distance are considered to be significant. Transport Canada should undertake this evaluation.

Effect of Decelerometer Type – Tests were done with the Electronic Recording Decelerometer (ERD Mk II and ERD Mk III), the Tapley, and the Bowmonk (which was set to record either the peak or the average friction coefficient). These decelerometers produced different values, which is similar to the results obtained during a test program in 2002. Instrumentation problems were encountered with the ERDs that make it difficult to make general statements; and to compare the MK II and Mk III. The ERD Mk III consistently read about 0.05 lower than did the Tapley over the full range of friction coefficients. This finding is similar to the result from the 2002 program. The relationship between the Bowmonk and the ERD Mk III depended upon whether peak or average Bowmonk values were compared.

The peak values read by the Bowmonk were both above and below the readings from the ERD Mk III. The maximum variation in friction coefficient between the Bowmonk peak and the ERD Mk III was about 0.1. The average values read by the Bowmonk were generally similar to those from the ERD Mk III, although only a few data points were obtained.

SOMMAIRE

Le présent projet porte sur les coefficients de frottement mesurés à l'aide de décéléromètres à des aéroports canadiens. Il comprend deux volets : (a) essais d'assurance de la qualité du Coefficient canadien de frottement sur piste (CRFI, pour *Canadian Runway Friction Index*) et (b) essais sur l'effet du système de freinage antiblocage (ABS).

Essais d'assurance de la qualité du CRFI – Ces essais avaient pour but de comparer les coefficients CRFI obtenus avec les décéléromètres en usage aux différents aéroports avec le système de Transports Canada (TC). Les véhicules d'essai étaient constitués de (a) le Blazer de TC et (b) un décéléromètre d'enregistrement électronique (ERD) Mk II. D. Booth, de l'aéroport de North Bay, était au volant du Blazer. Le système de Transports Canada a été utilisé tout au long du Programme conjoint de recherche sur la glissance des chaussées aéronautiques l'hiver (PCRGCAH), lancé en 1996. Les essais ont eu lieu à cinq aéroports du nord de l'Ontario et se sont étalés sur deux périodes, en janvier et février 2003. Pour chaque surface étudiée, des coefficients CRFI ont été établis à l'aide du système de Transports Canada et des véhicules en usage aux aéroports. Les essais ont été menés sur des surfaces opérationnelles plutôt que sur des surfaces spécialement preparées. Ces surfaces présentaient divers degrés de frottement. En outre, les conducteurs étaient appelés à s'échanger les véhicules.

Résultats :

- Les écarts entre les coefficients CRFI obtenus avec les systèmes aéroportuaires et avec celui de Transports Canada varient selon l'aéroport et le circuit. Comme prévu, les écarts observés entre les distances d'atterrissage recommandées (établies à partir des coefficients CRFI mesurés) étaient la plupart du temps minimes. En effet, dans 70 p. 100 des cas, celui-ci ne dépassait pas 500 pi. À son maximum, il s'établissait à 826 pi. (À noter que toutes les références faites aux distances d'atterrissage recommandées s'appliquent à une distance d'atterrissage non pondérée de 3 000 pi, sans inversion de poussée.)
- En général, les écarts les plus grands ont été observés aux aéroports qui font usage de l'ERD Mk III.
- Dans tous les cas, les résultats obtenus avec le conducteur de Transports Canada et le conducteur rattaché à l'aéroport ont été semblables. L'écart moyen entre les coefficients CRFI s'est établi à 0,013, avec un maximum de 0,04. Cela est probablement une indication que les conducteurs avaient tous reçu une formation semblable concernant l'utilisation des techniques de mesure. Donc, la permutation des conducteurs n'a pas eu d'effet significatif sur les coefficients CRFI, en comparaison des autres écarts observés entre les ensembles véhicule-décéléromètre.
- Les ERD utilisés dans le système de TC ont posé des problèmes d'instrumentation, ce qui limite la portée des conclusions qui peuvent être tirées des essais.

Il est recommandé de mener d'autres études sur les thèmes suivants : (a) la stabilité de la norme utilisée comme base de comparaison au cours des présents travaux; (b) l'étalonnage et la certification des décéléromètres; (c) l'acceptation et la réglementation des décéléromètres et (d) l'importance des écarts observés entre les coefficients CRFI.

Essais sur l'effet de l'ABS – Ces essais visaient à mesurer jusqu'à quel point le fait que le système ABS soit actionné ou non influe sur le coefficient CRFI. Ces essais ont permis d'enrichir la base de données constituée à la faveur d'un programme d'essais semblable mené en 2002; ils ont en effet permis d'évaluer : (a) un éventail plus large de véhicules; (b) plusieurs types de décéléromètres et (c) une gamme plus étendue de surfaces.

Résultats tirés de l'ensemble des données recueillies :

- L'effet du freinage avec ou sans ABS est tributaire du véhicule, du décéléromètre et de la surface étudiée. Aucune relation universelle n'a pu être établie, malgré que pour chaque véhicule, certaines tendances aient pu être dégagées. Ainsi, les effets les plus divers ont été constatés : par rapport au freinage sans ABS, le freinage avec ABS (i) augmentait le coefficient de frottement, (ii) diminuait le coefficient de frottement ou (iii) n'avait aucun effet. Dans certains cas, des écarts substantiels ont été mesurés entre les coefficients CRFI, selon que l'ABS du véhicule était actionné ou non.
- Pour évaluer l'importance des écarts observés entre coefficients de frottement, ceux-ci ont été examinés sous l'angle de leur effet sur les distances d'atterrissage recommandées. (À noter que toutes les références faites aux distances d'atterrissage recommandées s'appliquent à une distance d'atterrissage non pondérée de 3 000 pi, sans inversion de poussée.) Les écarts les plus grands ont été observés pour le camion ½ tonne et le camion ¾ de tonne (voir le tableau 1), le 24 février, au cours d'essais réalisés sur une piste nue recouverte de 6 mm (¼ po) de neige folle. Ce jour-là, seuls l'ERD Mk III et l'ERD Mk II ont servi à la collecte de données. Les appareils Tapley et Bowmonk n'ont pas été mis en œuvre pour raison d'indisponibilité.

Tableau 1 : Écart maximal entre les distances d'arrêt inférées, selon que le système de freinage utilise ou non l'ABS

	ERD MK III	ERD Mk II	Tapley	Bowmonk – valeur maximale	Bowmonk –valeur moyenne
Blazer	- 549	- 533	- 171	- 106	- 695
Camion ½ tonne	876	829	- 152	- 448	614
Camion ¾ tonne	924	853	41	220	aucune donnée
Camion 1 tonne	- 202	- 334	aucune donnée	aucune donnée	- 116
Voiture, traction arrière	- 302	- 310	- 189	- 256	aucune donnée
Voiture, traction avant	257	258	34	- 427	aucune donnée

Nota :

1. Les écarts sont donnés en pieds.
2. Un écart négatif ou positif indique que la distance d'atterrissage calculée à partir du coefficient de frottement mesuré sans ABS était plus courte ou plus longue, respectivement, que la distance avec ABS.

Les écarts maximaux donnés ci-dessus sont plus élevés que ceux observés au cours des essais de 2002, dont le plus élevé s'établissait à 449 pi. Cette différence peut être attribuable aux conditions de la surface, car en 2002, aucun essai n'a eu lieu sur une chaussée recouverte de neige folle. Les essais de 2002 ont tous été réalisés sur de la glace vive et de la neige tassée.

Pour ce qui est des suites à donner à ces résultats, il importe de déterminer l'importance des écarts ci-dessus. Il revient à Transports Canada de se prononcer sur cette question.

Effet du type de décéléromètre – Des essais ont été réalisés avec les décéléromètres à enregistrement électronique ERD Mk II et ERD Mk III, le Tapley, et le Bowmonk (ce dernier réglé pour enregistrer soit le coefficient de frottement maximal, soit le coefficient de frottement moyen). Tous ces décéléromètres ont enregistré des valeurs différentes, ce qui concorde avec les résultats obtenus au cours d'un programme d'essais en 2002. Du fait des problèmes d'instrumentation posés par les ERD, il est difficile de tirer des conclusions générales des essais et de comparer le MK II et le Mk III. Quant à l'ERD Mk III, il donnait systématiquement des valeurs environ 0,05 inférieures à celles données par le Tapley, dans toute la gamme des coefficients de frottement. Ce résultat concorde avec ce qui avait été observé au cours du programme d'essais de 2002. La relation entre le Bowmonk et l'ERD Mk III variait selon que l'on considérait les valeurs maximales ou moyennes recueillies à l'aide de l'appareil Bowmonk.

Ainsi, les valeurs maximales obtenues à l'aide de l'appareil Bowmonk étaient parfois supérieures, parfois inférieures aux valeurs obtenues à l'aide de l'ERD Mk III. L'écart maximal entre le coefficient de frottement maximal enregistré par le Bowmonk et celui enregistré par l'ERD Mk III était d'environ 0,1. Règle générale, les valeurs moyennes enregistrées par le Bowmonk concordaient avec celles enregistrées par l'ERD Mk III; il faut toutefois préciser que l'on ne dispose que d'un petit nombre de points de données.

TABLE OF CONTENTS

1. INTRODUCTION AND OBJECTIVES 1
  1.1 Background 1
  1.2 Objectives 2
    1.2.1 CRFI Quality Assurance Tests 2
    1.2.2 ABS Effect Tests 2

2. CRFI QUALITY ASSURANCE TESTS 4
  2.1 Test Program Scope 4
    2.1.1 Test Locations 4
    2.1.2 Test Dates 4
  2.2 Test Procedures and Conditions 4
    2.2.1 Test Procedures 4
    2.2.2 CRFI Testing Method 5
    2.2.3 Surfaces Tested 6
    2.2.4 Vehicles Tested 8
    2.2.5 Decelerometers Used 9
  2.3 Results: Measured Friction Coefficients 11
    2.3.1 Presentation of Raw Data 11
    2.3.2 CRFIs Measured by Transport Canada and Site Systems 18
    2.3.3 CRFIs Measured with the Operators Switched 20
    2.3.4 CRFIs Measured with the Operators and Vehicles Switched 21
  2.4 Inferred Landing Distances from the CRFI Results 22
    2.4.1 Purpose of Analyses 22
    2.4.2 Analysis Approach 22
    2.4.3 System Comparison: Inferred Landing Distances 24
    2.4.4 Effect of Operator on Inferred Landing Distances 27

3. EFFECT OF ABS ON OR OFF 30
  3.1 Objectives 30
  3.2 Test Method and Scope 30
    3.2.1 Test Location and Dates 30
    3.2.2 Test Vehicles 30
    3.2.3 Decelerometers Used 37
    3.2.4 Test Surfaces and Environmental Conditions 38
    3.2.5 Test Matrix 43
  3.3 Results: Measured Friction Coefficients 45
    3.3.1 Effect of ABS On v. Off: Results by Decelerometer and Vehicle Type 45
    3.3.2 Effect of Decelerometer Type 52
  3.4 Effect of ABS ON v. OFF On Inferred Landing Distances 56
    3.4.1 Analysis Purpose and Approach 56
    3.4.2 Effect of Decelerometer Type 56
    3.4.3 Effect of Vehicle Type on Inferred Landing Distance 59
  3.5 Discussion and Summary 62
    3.5.1 Effect of ABS On v. Off: Measured Friction Coefficients 62

3.5.2 Effect of ABS On v. Off: Inferred Landing Distances.....63
3.5.3 Decelerometer Comparison.....64
4. CONCLUSIONS AND RECOMMENDATIONS.....66
4.1 Conclusions.....66
4.1.1 CRFI Quality Assurance.....66
4.1.2 Effect of ABS Disabled or Not.....66
4.1.3 Effect of Decelerometer Type.....67
4.2 Recommendations.....68
4.2.1 CRFI Quality Assurance.....69
4.2.2 Effect of ABS Disabled or Not.....69
REFERENCES.....71

APPENDICES

APPENDIX A: VEHICLES AND PROCEDURES USED DURING THE CRFI ASSURANCE TESTS
APPENDIX B: RAW DATA FOR THE CRFI ASSURANCE TESTS
APPENDIX C: TEST SURFACES FOR THE CRFI ASSURANCE TESTS
APPENDIX D: SUMMARY TEST DATA FOR THE ABS EFFECT TESTS

LIST OF FIGURES

Figure 2.1: Airport 1 Test Surfaces 7
Figure 2.2: ERD Mk II v. ERD Mk III in the Transport Canada System for Circuit 2 11
Figure 2.3: Raw Data Chart for Airport 1 - Circuit 1 12
Figure 2.4: CRFIs Measured by TC and Site Systems for Circuits 1 and 2 19
Figure 2.5: CRFIs Measured by TC and Site Systems for Circuit 1 19
Figure 2.6: CRFIs Measured by TC and Site Systems for Circuit 2 20
Figure 2.7: CRFIs Measured with the Operators Switched for Circuits 1 and 2 21
Figure 2.8: CRFIs Measured with the Operators Switched for Circuits 1 and 2 22
Figure 2.9: Landing Distances in the AIP [3] for No Reverse Thrust 23
Figure 2.10: Inferred Landing Distance Comparison for the CRFI Systems 25
Figure 2.11: Histogram of Inferred Landing Distance Variations 26
Figure 2.12: Exceedence Probabilities for Inferred Landing Distance Variations 26
Figure 2.13: Comparison with Operators Switched: Inferred Landing Distances 27
Figure 2.14: Histogram of Inferred Landing Distance Variations 29
Figure 2.15: Exceedence Probabilities for Inferred Landing Distance Variations 29
Figure 3.1: The Blazer 33
Figure 3.2: The 2x4 Ford ½-Ton Truck 33
Figure 3.3: The 4x4 Chevrolet ½-Ton Truck 34
Figure 3.4: The Dodge 4x4 Windsor Airport ½-Ton Truck 34
Figure 3.5: The ¾-Ton Truck 35
Figure 3.6: The 1-Ton Truck 35
Figure 3.7: The RWD Car 36
Figure 3.8: The FWD Car 36
Figure 3.9: Ice Surface 39
Figure 3.10: Ice Surface 39
Figure 3.11: Loose Snow on Pavement 40
Figure 3.12: Loose Snow on Pavement 40
Figure 3.13: Loose Snow on Packed Snow 41
Figure 3.14: Loose Snow on Packed Snow 41
Figure 3.15: Sanded Partly Consolidated Snow on Pavement 42
Figure 3.16: Sanded Partly Consolidated Snow on Pavement 42
Figure 3.17: Decelerometer Comparison for the Blazer: All Test Surfaces 47
Figure 3.18: Decelerometer Comparison for the ½-Ton Truck: All Test Surfaces 47
Figure 3.19: Decelerometer Comparison for the ¾-Ton Truck: All Test Surfaces 48
Figure 3.20: Decelerometer Comparison for the 1-Ton Truck: All Test Surfaces 48
Figure 3.21: Decelerometer Comparison for the RWD Car: All Test Surfaces Combined 49
Figure 3.22: Decelerometer Comparison for the FWD Car: All Test Surfaces Combined 49
Figure 3.23: Effect of Vehicle for the ERD Mk III: All Test Surfaces Combined 50
Figure 3.24: Effect of Vehicle for the ERD Mk II: All Test Surfaces Combined 50
Figure 3.25: Effect of Vehicle for the Bowmonk: All Test Surfaces Combined 51
Figure 3.26: Effect of Vehicle for the Tapley: All Test Surfaces Combined 51
Figure 3.27: Decelerometer Comparison: ERD Mk II v. ERD Mk III 54
Figure 3.28: Decelerometer Comparison: Bowmonk (Peak) v. ERD Mk III 54

Figure 3.29: Decelerometer Comparison: Bowmonk (Average) v. ERD Mk III 55
Figure 3.30: Decelerometer Comparison: Tapley v. ERD Mk III 55
Figure 3.31: Inferred Landing Distances: Decelerometer Comparison for the Blazer for All Test Surfaces Combined 56
Figure 3.32: Inferred Landing Distances: Decelerometer Comparison for the ½-Ton for All Test Surfaces Combined 57
Figure 3.33: Inferred Landing Distances: Decelerometer Comparison for the ¾-Ton for All Test Surfaces Combined 57
Figure 3.34: Inferred Landing Distances: Decelerometer Comparison for the 1-Ton for All Test Surfaces Combined 58
Figure 3.35: Inferred Landing Distances: Decelerometer Comparison for the RWD Car for All Test Surfaces Combined 58
Figure 3.36: Inferred Landing Distances: Decelerometer Comparison for the FWD Car for All Test Surfaces Combined 59
Figure 3.37: Effect on Inferred Landing Distances: Vehicle Comparison for the ERD Mk III for All Test Surfaces Combined 60
Figure 3.38: Effect on Inferred Landing Distances: Vehicle Comparison for the ERD Mk II for All Test Surfaces Combined 60
Figure 3.39: Effect on Inferred Landing Distances: Vehicle Comparison for the Bowmonk for All Test Surfaces Combined 61
Figure 3.40: Effect on Inferred Landing Distances: Vehicle Comparison for the Tapley for All Test Surfaces Combined 61
Figure 3.41: Effect of ABS On v. Off: Results from 2002 for the ERD Mk III [1] 62
Figure 3.42: Effect on Inferred Landing Distances During the 2002 Tests [1]: ABS On or Off for the ERD Mk III for All Test Surfaces Combined 63

LIST OF TABLES

Table 2.1: Airports Tested and Test Dates....4
Table 2.2: Summary of Test Temperatures....6
Table 2.3: Vehicle Description....8
Table 2.4: Vehicle Weights and Contact Pressures....9
Table 2.5: Decelerometers Used....10
Table 2.6: Airport 1 Summary CRFI Data....13
Table 2.7: Airport 2 Summary CRFI Data....14
Table 2.8: Airport 3 Summary CRFI Data....15
Table 2.9: Airport 4 Summary CRFI Data....16
Table 2.10: Airport 5 Summary CRFI Data....17
Table 2.11: System Comparison: Variation Among Airports for Inferred Landing Distances....24
Table 2.12: Comparison with Operators Switched: Variation among Airports for Inferred Landing Distances....28
Table 3.1: Vehicle Information....31
Table 3.2: Vehicle Weight and Tire Contact Pressure....32
Table 3.3: Decelerometers used for the ABS Tests....37
Table 3.4: Temperature and Wind Conditions....38
Table 3.5: Test Matrix: February 24 Tests....43
Table 3.6: Test Matrix: February 25 Tests....44
Table 3.7: Test Matrix: February 26 Tests....44
Table 3.8: Test Matrix: February 27 Tests....45
Table 3.9: Effect of ABS On v. Off....46
Table 3.10: Effect of Decelerometer Type....53
Table 3.11: Maximum Variation in Inferred Landing Distances for ABS On v. Off....63
Table 3.12: Effect of ABS On or Off for the 2002 Tests [1]: Maximum Differences in Inferred Landing Distances....64
Table 4.1: Maximum Variation in Inferred Landing Distances for ABS On v. Off....67

GLOSSARY

ABS	Antilock Braking System
AIP	Aeronautical Information Publication
BMT FTL	BMT Fleet Technology Limited
CRFI	Canadian Runway Friction Index
ERD	Electronic Recording Decelerometer
FAA	Federal Aviation Administration
FWD	Front Wheel Drive
JWRFMP	Joint Winter Runway Friction Measurement Program
LD	Landing Distance
RWD	Rear Wheel Drive
SUV	Sport Utility Vehicle
TC	Transport Canada

1. INTRODUCTION AND OBJECTIVES

Runway friction data are a fundamental requirement at Canadian airports for maintaining a satisfactory safety level when aircraft land and take off on runways covered with winter contaminants. Surface conditions such as ice, snow, wet ice, and chemically treated winter surfaces are a hazard to safe aircraft operations. Meaningful and credible friction information is needed from pilots to make proper decisions on whether to safely land his/her aircraft. The provision of runway friction information is internationally recognized as critical for global aviation safety.

1.1 Background

During the winter season, airports in Canada conduct runway surface inspections and forward this information to air traffic control or flight service stations for onward transmission to pilots. The friction of the runway is an essential part of the information collected. Airports take friction measurements throughout inclement winter weather periods when winter contaminants such as snow, ice, compacted snow and other contaminants are on the runway.

Various devices are used throughout the world to measure and report runway friction. In Canada, airports have used, and continue to use, decelerometers for friction measurement in wintertime. These measurements are made by mounting a decelerometer in a vehicle. To take a measurement, the vehicle is induced to skid, and its deceleration is recorded. The friction number that these instruments provide are averaged over the length of the runway, and called the Canadian Runway Friction Index (CRFI). It is fundamental to the provision of the CRFI that:

- the decelerometers in service at Canadian airports are being used properly;
- they produce the same number when operated in the same vehicle;
- they are regularly serviced as required; and
- the vehicles used as platforms for decelerometers are appropriate, and properly maintained.

It is important to recognize that this friction-measuring system has three major components:

- the decelerometer instrument – although the Electronic Recording Decelerometer (ERD) is most commonly used at Canadian airports, other decelerometers are available.
- the vehicle – airports in Canada use a variety of vehicles as the platform for friction measurements with decelerometers.
- the operator – it is well known that results can vary with different operators.

This was a two-part project undertaken to investigate the friction coefficients produced by decelerometers at Canadian airports.

1.2 Objectives

This project had two major parts as follows:

(a) CRFI Quality Assurance Tests
(b) Antilock Braking System (ABS) effect tests

1.2.1 CRFI Quality Assurance Tests

The objective was to compare the CRFIs obtained with decelerometer systems in use at different airports with the Transport Canada system, which consisted of the following:

- the Transport Canada Blazer (described in Section 2);
- the ERD – although both the ERD Mk II and the ERD Mk III were mounted in the Blazer, the ERD Mk II was used as the basis of comparison; and
- D. Booth, of North Bay airport, who operated the Blazer.

Tests were conducted at five airports in northern Ontario during two periods in January and February. CRFIs were obtained with the Transport Canada system and the sites' vehicles on the same surface. It should be noted that the tests were not done on prepared surfaces but rather on operational surfaces at the airports. The surfaces were selected to span a range of friction levels.

The second objective was to assess the effect of the operator on any variability that might be observed. To this end, tests were done with the operators switched, as follows:

- the Transport Canada Blazer was operated by the site's operator;
- D. Booth, of North Bay airport, operated the site's system.

1.2.2 ABS Effect Tests

Friction measurements at Canadian airports are now made with the vehicle's ABS braking system disabled. This practice stems from previous tests that showed that the friction coefficients measured with the vehicle's ABS system on were substantially different from those obtained with the ABS system off. Transport Canada standardized friction testing at that time by disabling the vehicle's ABS systems as this eliminated this variable and improved the credibility of the friction reporting process. However, it is becoming increasingly difficult for airports to disable the ABS system for friction measurement. Most current vehicles have ABS systems as standard equipment. Furthermore, ABS systems are becoming increasingly complex, which makes them more difficult to disable. Also, liability issues arise when vehicles are operated with the ABS system off.

Recent tests in January, 2002 at North Bay airport cast doubt on the need to disable the ABS system [1]. It was indicated that the friction readings were not greatly affected by whether or not the vehicle's ABS was on or off. Because this finding was at variance with current recommendations (by Transport Canada, Federal Aviation Administration (FAA) and the decelerometer manufacturers), and it was based on a relatively small database, it was decided that additional testing was required. The objective of the testing was to establish the degree to which friction coefficients are affected by whether or not the vehicle's ABS is on or off. The testing was aimed at evaluating this for:

- a wide range of vehicles;
- several decelerometer types; and
- a wide range of winter surfaces.

2. CRFI QUALITY ASSURANCE TESTS

2.1 Test Program Scope

2.1.1 Test Locations

Tests were done at airports in Sudbury, Kapuskasing, North Bay Jack Garland, Sault Ste. Marie, and Timmins (Table 2.1).

Table 2.1: Airports Tested and Test Dates

Airport	Contact Person at Airport	Test Dates for Circuit 1	Test Dates for Circuit 2
Great Sudbury Airport	Don Dunlop	January 10	February 6
Kapuskasing Airport	Rock Robitaille,	January 15	February 4
North Bay Jack Garland	Hector Gauthier	January 9 and 13	February 6
Sault Ste. Marie Airport	Don Vallée	January 11	February 10
Timmins Airport	Ivan Perreault	January 14	February 5

These airports were selected for a number of reasons:

- they are all relatively close to North Bay which would allow the project to be conducted efficiently;
- they are all located in regions where a range of winter surfaces can be expected; and
- discussions at the start of the project with the appropriate airport staff indicated that these airports would be willing to cooperate in such a project.

Because this was an exploratory research program, it was agreed that the results from each airport would not be specifically identified in this report. As a result, the results are presented as Airports 1 through 5 in random order.

2.1.2 Test Dates

Tests were performed by traveling to each airport in turn with the Transport Canada system. Tests were done in two circuits, as summarized below, and listed in Table 2.1.

- Circuit 1 – January 9-14, 2003
- Circuit 2 – February 4-10, 2003

2.2 Test Procedures and Conditions

2.2.1 Test Procedures

The program was set up to not interfere with the normal operations of the airports. Thus, the test schedule was kept flexible to the extent possible. Excellent cooperation was obtained from each airport.

Each test day began with a meeting with the airport staff. Testing involved the following steps:

- The vehicles were documented. This included weighing them and measuring the tire footprint area. Detailed procedures for these measurements are provided in Appendix A. Other pertinent vehicle data were also recorded as described in section 2.2.4.
- Test surfaces were selected. This was done by driving out onto the airfield and inspecting the available surfaces. Surfaces were selected to cover a range of friction levels. At least two different surfaces were always tested.
- CRFI tests were conducted as described in section 2.2.2 to:
  - compare the CRFIs obtained from the site and the Transport Canada system; and
  - evaluate the effect of the operator. (This was done by switching operators in the test vehicles.)

2.2.2 CRFI Testing Method

Initially, both operators calibrated their devices on the level ground commonly used by the site.

The site was instructed to use the same testing method that they would normally use for friction measurement during regular Runway Condition Reporting. It was observed that all operators applied the brakes in a similar fashion. The only noticeable difference between operators was the length of time that they held the brake down to ensure that a valid CRFI was collected.

Typically, testing was done by having the site operator drive a short distance (about 500 ft.) ahead of the TC operator. In all cases, the vehicle was accelerated to 50 km/h and then the brakes were applied.

A minimum of 15 readings was collected per run. This data quantity was selected as previous analyses [2] have shown that the reliability of the friction coefficients measured by the ERD on winter surfaces did not increase significantly with additional measurements.

Although the friction data were not analyzed on a point-by-point basis, efforts were made to synchronize the two data sets by collecting them at nearby locations. The runway lights were used for this purpose as the site operator was asked to apply the brakes at a regular interval of runway lights. The TC operator (following behind) used these as reference points for applying his vehicle's brakes, while keeping his vehicle's path slightly offset from the existing skids to avoid testing on previously skidded surfaces.

During Circuit 1, a BMT FTL representative responsible for tagging the CRFI data strips for subsequent data entry accompanied both operators. During Circuit 2, the TC operator drove alone, and tagged his vehicle's CRFI reading strips while a BMT FTL representative accompanied the site operator.

The test matrix included tests with the operators switched. This was done to allow the effect of different operators to be evaluated. Except for the airport 5 data, the odd-numbered data sets (Runs 1, 3, and 5) were collected using the "original" systems, with the site operator running the site vehicle, and D. Booth running the Transport Canada system. The even-numbered data sets (Runs 2, 4, and 6) were collected by switching operators.

At airport 5, runs 1, 2, 3, 4, and 6 were done with "original" systems. The operators were switched for runs 5 and 7. Summary data are presented in Section 2.3.

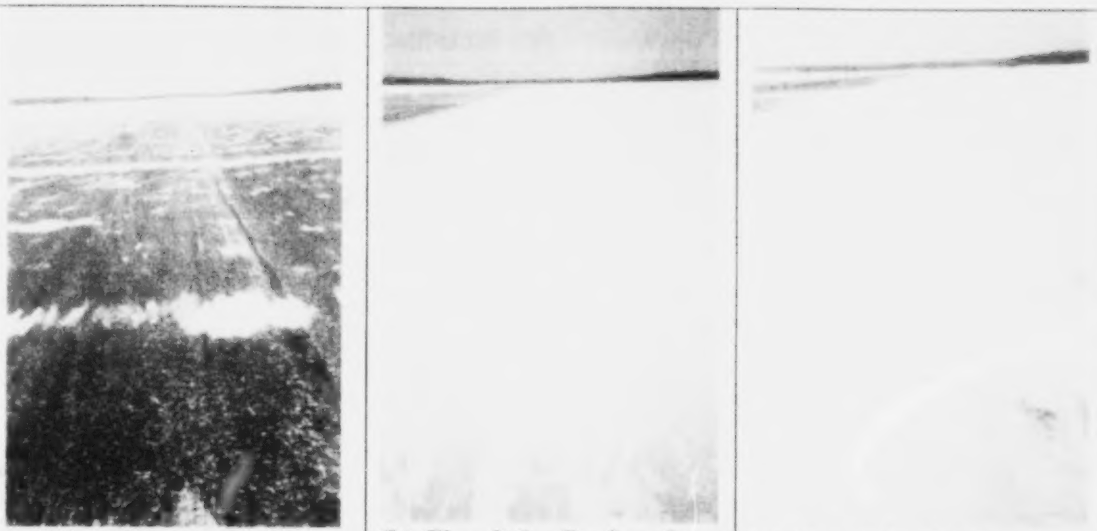
2.2.3 Surfaces Tested

Following each test, the surface was photographed, and the air and ground temperatures were measured (Appendix B and Table 2.2). Wind information was gathered from each airport's weather office (Appendix B). Appendix B also provides general surface descriptions for each surface. The location of the runs was also recorded, but these are withheld to maintain anonymity.

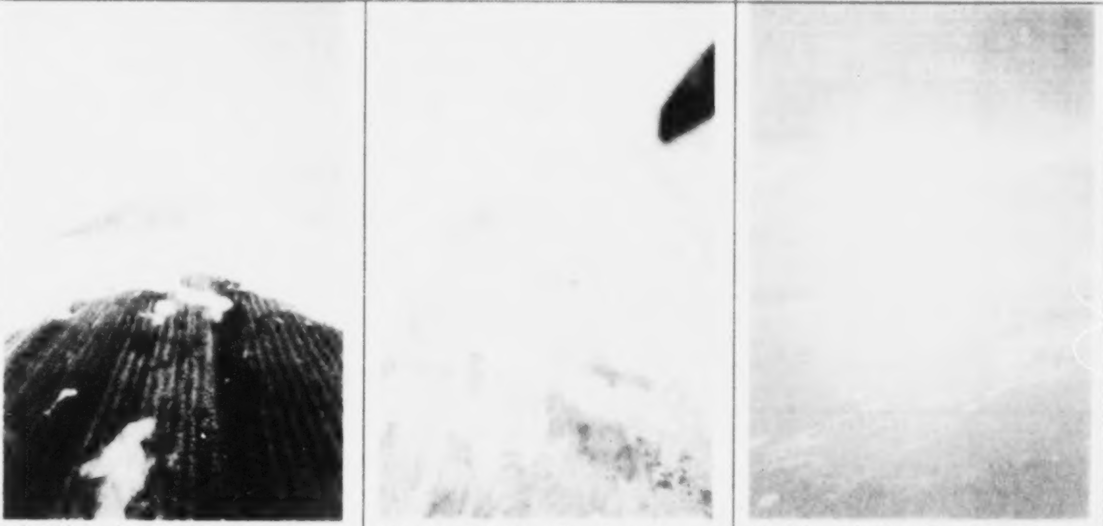
No test surfaces were specially prepared for this program; all tests were done on operational surfaces at the airports. Sample surfaces are shown in Figure 2.1. All of the surfaces tested are shown in Appendix C.

Table 2.2: Summary of Test Temperatures

	Circuit 1		Circuit 2	
Airport	**Air Temp (°C)**	**Surface Temp (°C)**	**Air Temp (°C)**	**Surface Temp (°C)**
Airport 1	-23.5	-22.4 to -23.2	-15.9 to -16.6	-14.9 to -16
Airport 2	-20.9 to -23.7	-20.7 to -21.9	-23.4 to -24.4	-17.2 to -23.5
Airport 3	-16.7 to -20.5	-12.9 to -14.3	-15.9 to -18.3	-15 to -17.2
Airport 4	-6.6 to -7	-5.6	-18 to -19	-13.6 to -18.3
Airport 5	-11 to -15.6	-6.9 to -15.6	-17 to -17.6	-14.4 to -15.6



(a) Circuit 1 – Surface 1 (b) Circuit 1 – Surface 2 (c) Circuit 1 – Surface 3



(d) Circuit 2 – Surface 1 (e) Circuit 2 – Surface 2 (f) Circuit 2 – Surface 3

Figure 2.1: Airport 1 Test Surfaces

2.2.4 Vehicles Tested

Table 2.3 describes each vehicle that was tested while Table 2.4 summarizes the weight and contact pressure for each vehicle. Photographs of all vehicles are provided in Appendix A.

Table 2.3: Vehicle Description

Vehicle - General								
Location	Transport Canada	Airport 1	Airport 2		Airport 3		Airport 4	Airport 5
Manufacturer	Chevrolet	GMC	Ford	Chevrolet	Chevrolet	GMC	Chevrolet	Ford
Model	Blazer	1500 Cheyenne	F350	1500 Silverado	2500 Cheyenne	2500 SL	1500 Cheyenne	F150XL
Year	1991	1992	1996	2003	1997	1993	1989	2002
Odometer (km)	113,645	97,097	93,452	2,791	100,199	117,154	119,981	13,941
Wheelbase, m (in)	2.74 (108)	3.35 (132)	4.27 (168)	3.35 (132)	3.35 (132)	3.35 (132)	3.35 (132)	3.04 (120)
Vehicle - Antilock Braking System (ABS)								
Type	4 wheel	None	4 wheel	4 wheel	4 wheel	None	None	4 wheel
On/Off	Off	-	Off	Off	Off	-	-	Off
Vehicle - Tires								
Size	P235/75 R15	245/75 R16	235/85 R16	255/70 R16	LT245/75 R16	LT225/75 R16	P235/75 R15	P235/70 R16
Brand	Michelin	Toyo radials		Ameritrak	Marshal	Merit	Hercules	BF Goodrich
Type/Season	M + S	All season	M+S	M+S	All season	All season	M+S	All season
Pressure, kPa (psi)	241 (35)	193 (28)	276 (40)	front 221 (32) rear 241 (35)	front 241 (35) rear 276 (40)	front 248 (36) rear 276 (40)	241 (35)	248 (36)
Tread Depth (mm)	9.0	N.A.	front 9.0 rear 12.0	front 7.0 rear 8.0	front 8.5 rear 5.2	front 8.0 rear 5.0	3.75	5.5

Table 2.4: Vehicle Weights and Contact Pressures

Vehicle - General								
Location	Transport Canada	Airport 1	Airport 2		Airport 3		Airport 4	Airport 5
Manufacturer	Chevrolet	GMC	Ford	Chevrolet	Chevrolet	GMC	Chevrolet	Ford
Model	Blazer	1500 Cheyenne	F350	1500 Silverado	2500 Cheyenne	2500 SL	1500 Cheyenne	F150XL
Total Vehicle Weight [lb.]								
	5200	6360	6240	5410	6715	5470	4620	5205
Weight/Tire [lb.]								
Front Pass.	1050	1940	1410	1260	1725	1110	1070	1050
Front Driver	1620	1950	1890	1630	1860	1140	1390	1630
Rear Pass.	1270	1220	1380	1270	1670	1650	1010	1275
Rear driver	1260	1250	1560	1250	1460	1570	1150	1250
Weight/Tire [kN]								
Front Pass.	4.670	8.629	6.272	5.604	7.673	4.937	4.759	4.670
Front Driver	7.206	8.674	8.407	7.250	8.273	5.071	6.183	7.250
Rear Pass.	5.649	5.427	6.138	5.649	7.428	7.339	4.492	5.671
Rear driver	5.604	5.560	6.939	5.560	6.494	6.983	5.115	5.560
Tire Print Contact Area[1] [mm^2]								
Front Pass.	14,173	34,677	18,669	16,743	15,081	14,839	19,677	19,544
Front Driver	13,710	30,443	19,335	19,379	21,835	14,677	18,992	17,314
Rear Pass.	11,573	20,282	17,944	21,155	15,121	20,726	17,823	18,177
Rear driver	11,169	25,524	17,399	20,329	17,944	22,016	18,750	17,472
Tire-Surface Pressure[2] [MPa]								
Front Pass.	0.330	0.249	0.336	0.335	0.509	0.333	0.242	0.239
Front Driver	0.526	0.285	0.435	0.374	0.379	0.345	0.326	0.419
Rear Pass.	0.488	0.268	0.342	0.267	0.491	0.354	0.252	0.312
Rear driver	0.502	0.218	0.399	0.274	0.362	0.317	0.273	0.318
Total Vehicle-Surface Contact Pressure[3] [kPa]								
	457	255	378	310	427	337	273	319

Note:

1. This was defined as: the overall footprint area less the area of the grooves not in contact with the surface.
2. This was defined as: Weight on Tire/Tire Print Contact Area.
3. This was defined as: Total Vehicle Weight/Total Tire Contact Area (i.e., for all 4 tires).
4. The above weights do not include the weight of the operator.

2.2.5 Decelerometers Used

The decelerometers each had a valid calibration record from which the calibration data was taken. The decelerometer information is reported in Table 2.5.

2.2.5.1 ERD Mk II in the Transport Canada System

Transport Canada's ERD Mk II (serial #0179) was used for Circuit 1 (Table 2.5) as it had been used during previous JWRFMP testing. This ERD MK II was selected to be consistent with previously collected data.

Following completion of Circuit 1, but before Circuit 2, the Transport Canada system (i.e., the Blazer, ERD MK II serial # 0179, and D. Booth) was used in the tests done at North Bay Jack Garland Airport as part of the 2003 JWRFMP.

The TC operator informed BMT FTL that sometime during the JWRFMP testing, ERD Mk II serial #0179 seemed to be experiencing or causing interference. As a result, ERD Mk II serial #0179 was replaced by ERD Mk II serial #0219, another Transport Canada ERD, during the 2003 JWRFMP. The reasons for the instrumentation problems with ERD Mk II serial #0179 are unknown.

ERD Mk II serial #0219 was used in the Transport Canada system for Circuit 2.

Table 2.5: Decelerometers Used

	Transport Canada - Blazer		Airport 1	Airport 2	Airport 3 (In Chev 2500 Cheyenne)	Airport 3 (In GMC 2500)	Airport 4	Airport 5
Model	ERD Mk II	ERD Mk III	ERD Mk II	ERD Mk III	ERD Mk II	ERD Mk III	ERD Mk III	ERD Mk II
Serial	Circuit 1: 0179 Circuit 2: 0219	024	0125	119	0123	181	039	0002
Last Calculation Date	Circuit 1: Dec. 2002 Circuit 2: Nov. 2002	Circuit 1: Sept. 2002 Circuit 2: Jan 2003	Sept. 2002	July 2002	Sept. 2002	Sept. 2002	Nov. 2002	Sept. 2002

2.2.5.2 ERD Mk III in the Transport Canada System

The ERD Mk III provided by Transport Canada was used for Circuit 1 and Circuit 2. However, because it was later found to be out of calibration, the data collected with this device for Circuit 1 were not used for subsequent analyses. However, the friction coefficients from the ERD Mk III are listed in this report for completeness.

It was recalibrated between Circuits 1 and 2, and then used in Circuit 2. However, to be consistent with the Circuit 1 data, the ERD Mk III data were not used for subsequent analyses, and all comparisons were done using the ERD Mk II data only. This decision had no effect on the conclusions of the testing as the ERD Mk II (serial #0219) and the ERD MK III (serial #024) recorded similar values during Circuit 2 (Figure 2.2).

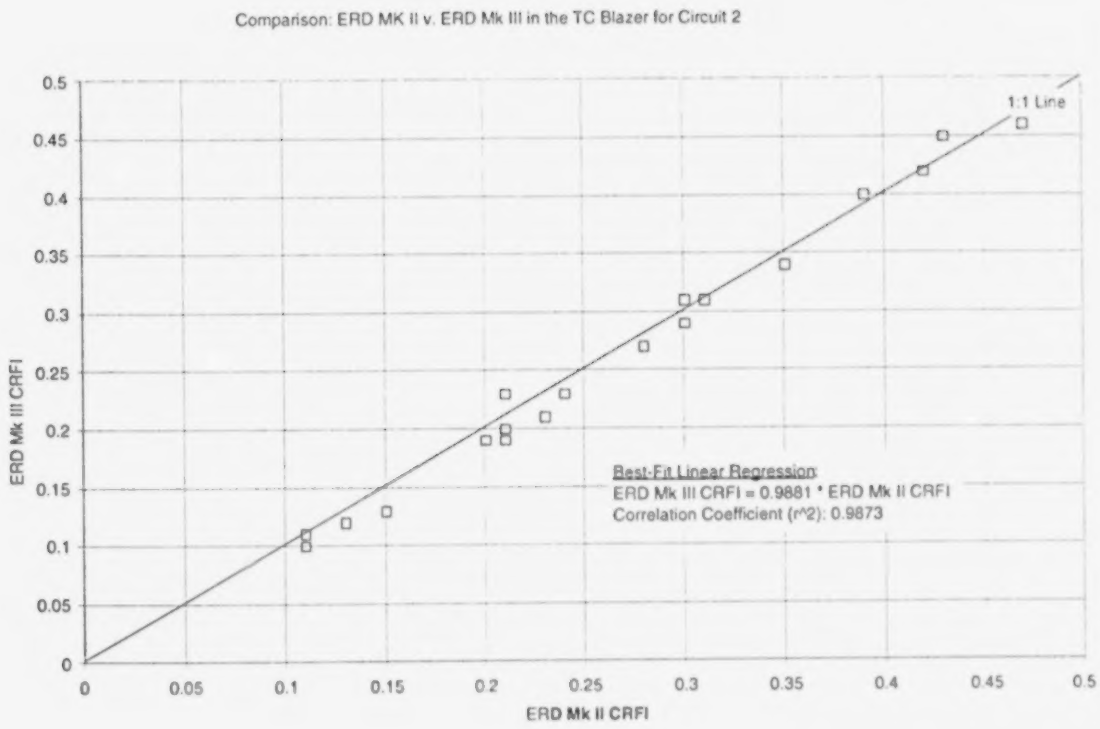


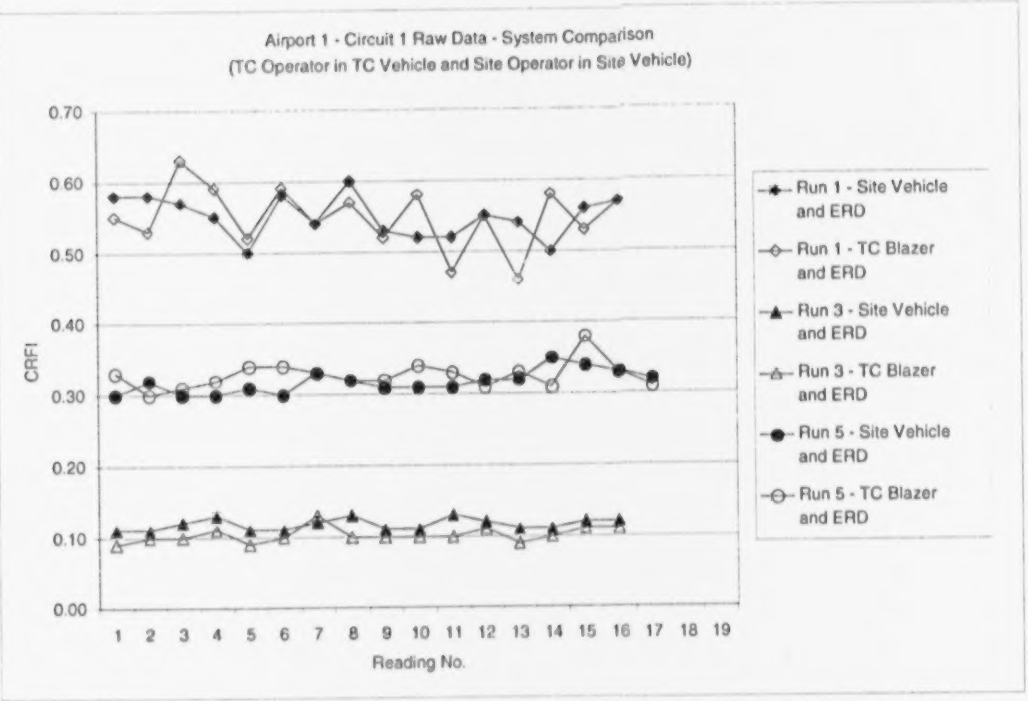
Figure 2.2: ERD Mk II v. ERD Mk III in the Transport Canada System for Circuit 2

2.3 Results: Measured Friction Coefficients

2.3.1 Presentation of Raw Data

The average CRFIs are summarized in Tables 2.6 to 2.10 for Airports 1 to 5, respectively. These averages have been used for all subsequent analyses in this report. The raw CRFI data points are listed in Appendix B.

Figure 2.3 shows a sample of the raw data originating from the runs on Circuit 1. The data are paired by vehicle and run number. The ERD Mk II data is shown from the TC reference vehicle. A full set of these plots is provided in Appendix B.



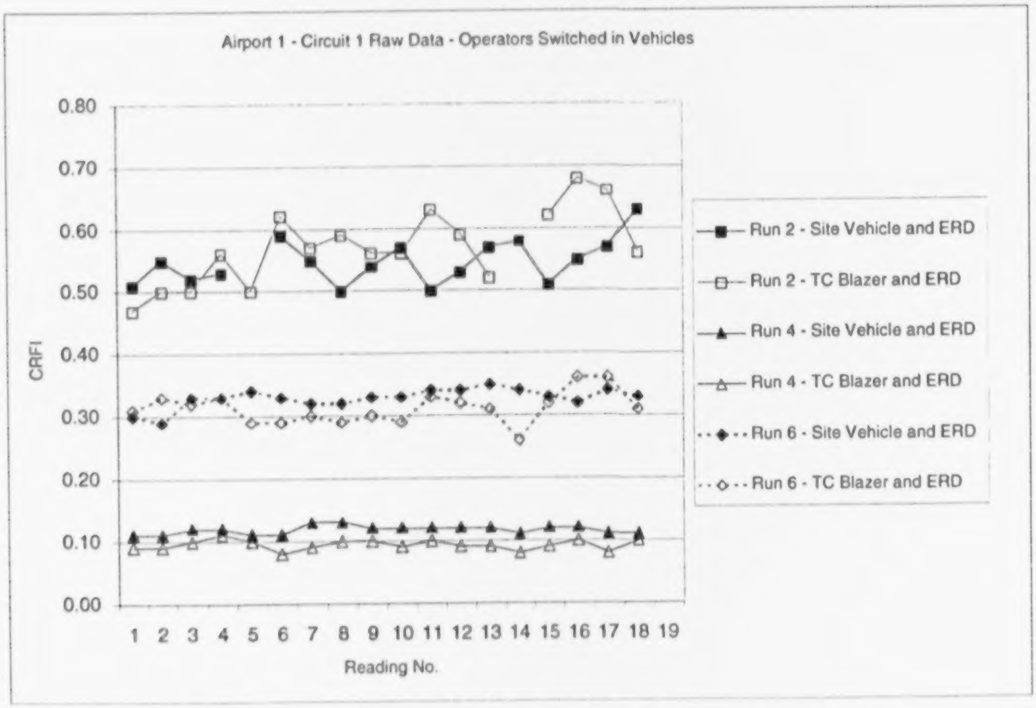


Figure 2.3: Raw Data Chart for Airport 1 - Circuit 1

Table 2.6: Airport 1 Summary CRFI Data

Vehicle	Operator	Average CRFI
CIRCUIT 1		
Surface: Dusting of Snow on Bare and Dry		
Run 1		
TC Blazer	TC Operator	0.55
Site Vehicle	Site Operator	0.55
Run 2		
TC Blazer	Site Operator	0.57
Site Vehicle	TC Operator	0.55
Surface: Light Dusting of Snow on Prepared Ice		
Run 3		
TC Blazer	TC Operator	0.10
Site Vehicle	Site Operator	0.12
Run 4		
TC Blazer	Site Operator	0.09
Site Vehicle	TC Operator	0.12
Surface: Compact Snow with Little Sand		
Run 5		
TC Blazer	TC Operator	0.33
Site Vehicle	Site Operator	0.32
Run 6		
TC Blazer	Site Operator	0.31
Site Vehicle	TC Operator	0.33
CIRCUIT 2		
Surface: Patchy and Blowing Snow over Bare		
Run 1		
TC Blazer	TC Operator	0.43
Site Vehicle	Site Operator	0.42
Run 2		
TC Blazer	Site Operator	0.42
Site Vehicle	TC Operator	0.44
Surface: Packed Snow and Ice due to Freezing Rain Three Days Earlier		
Run 3		
TC Blazer	TC Operator	0.27*
Site Vehicle	Site Operator	0.28
Run 4		
TC Blazer	Site Operator	0.24
Site Vehicle	TC Operator	0.24
Surface: Ice		
Run 5		
TC Blazer	TC Operator	0.11
Site Vehicle	Site Operator	0.13
Run 6		
TC Blazer	Site Operator	0.11
Site Vehicle	TC Operator	0.14

* The TC ERD Mark II data was lost due to a lack of power during printing. The three devices were subsequently printed individually. The ERD Mark III value is reported here.

Table 2.7: Airport 2 Summary CRFI Data

Vehicle	Operator	Average CRFI
CIRCUIT 1		
Surface: Packed Snow		
Run 1		
TC Blazer	TC Operator	0.27
Site Vehicle	Site Operator	0.22
Run 2		
TC Blazer	Site Operator	0.27
Site Vehicle	TC Operator	0.25
Surface: Sanded Packed Snow (Patchy Sand)		
Run 3		
TC Blazer	TC Operator	0.31
Site Vehicle	Site Operator	0.28
Run 4		
TC Blazer	Site Operator	0.31
Site Vehicle	TV Operator	0.30
Surface: Packed Snow Over Ice With Patches of Sand		
Run 5		
TC Blazer	TV Operator	0.30
Site Vehicle	Site Operator	0.26
Run 6		
TC Blazer	Site Operator	0.29
Site Vehicle	TC Operator	0.28
CIRCUIT 2		
Surface: Compact Snow		
Run 1		
TC Blazer	TC Operator	0.15
Site Vehicle	Site Operator	0.12
Run 2		
TC Blazer	Site Operator	0.13
Site Vehicle	TC Operator	0.09
Surface: Sanded Packed Snow Over Ice		
Run 3		
TC Blazer	TC Operator	0.23
Site Vehicle	Site Operator	0.16
Run 4		
TC Blazer	Site Operator	0.21
Site Vehicle	TC Operator	0.14

Table 2.8: Airport 3 Summary CRFI Data

Vehicle	Operator	Average CRFI
CIRCUIT 1		
Surface: 1/8 in. Loose Snow Over Ice		
Run 1		
TC Blazer	TC Operator	0.27
Site Vehicle	Site Operator	0.24
Run 2		
TC Blazer	Site Operator	0.28
Site Vehicle	TC Operator	0.26
Surface: 1/8 in. to ¼ in. Loose Snow on Packed Snow		
Run 3		
TC Blazer	TC Operator	0.30
Site Vehicle	Site Operator	0.23
Run 4		
TC Blazer	Site Operator	0.28
Site Vehicle	TC Operator	0.22
Surface: 1/8 in. Loose Snow Over Ice		
Run 5		
TC Blazer	TC Operator	0.27
Site Vehicle	Site Operator	0.27
Run 6		
TC Blazer	Site Operator	0.27
Site Vehicle	TC Operator	0.27
CIRCUIT 2		
Surface: ¼ in. Loose Snow Over Packed Snow		
Run 1		
TC Blazer	TC Operator	0.30
Site Vehicle	Site Operator	0.22
Run 2		
TC Blazer	Site Operator	0.30
Site Vehicle	TC Operator	0.20
Surface: Packed Snow Over Ice		
Run 3		
TC Blazer	TC Operator	0.21
Site Vehicle	Site Operator	0.12
Run 4		
TC Blazer	Site Operator	0.20
Site Vehicle	TC Operator	0.11
Surface: ¼ in. Loose Snow over Packed Snow		
Run 5		
TC Blazer	TC Operator	0.28*
Site Vehicle	Site Operator	0.22*

*This was a mixed test, and consequently, it was not used in the analyses. The ERD that was in the Transport Canada system was placed in the site vehicle, and the site's ERD was placed in the TC vehicle. This test was done on the same surface as the one used for Run 1.

Table 2.9: Airport 4 Summary CRFI Data

Vehicle	Operator	Average CRFI
CIRCUIT 1		
Surface: ½ in. Loose Snow Over Ice		
Run 1		
TC Blazer	TC Operator	0.19
Site Vehicle	Site Operator	0.20
Run 2		
TC Blazer	Site Operator	0.18
Site Vehicle	TC Operator	0.18
Surface: ½ in. Loose Snow Over Compact Snow		
Run 3		
TC Blazer	TC Operator	0.20
Site Vehicle	Site Operator	0.21
Run 4		
TC Blazer	Site Operator	0.20
Site Vehicle	TC Operator	0.22
Surface: Swept but Remaining Dusting		
Run 5		
TC Blazer	TC Operator	0.36*
Site Vehicle	Site Operator	0.39*
Run 6		
TC Blazer	Site Operator	0.35*
Site Vehicle	TC Operator	0.46*
CIRCUIT 2		
Surface: Packed Snow with 1/8 in. Loose Snow		
Run 1		
TC Blazer	TC Operator	0.35
Site Vehicle	Site Operator	0.28
Run 2		
TC Blazer	Site Operator	0.31
Site Vehicle	TC Operator	0.28
Surface: Packed Snow Over Ice		
Run 3		
TC Blazer	TC Operator	0.21
Site Vehicle	Site Operator	0.21
Run 4		
TC Blazer	Site Operator	0.21
Site Vehicle	TC Operator	0.19

* The surface was not homogeneous enough to collect comparable readings between the two vehicles.

Table 2.10: Airport 5 Summary CRFI Data

Vehicle	Operator	Average CRFI
CIRCUIT 1		
Surface: Sanded Ice – Formed From Packed Snow		
Run 1		
TC Blazer	TC Operator	0.34
Site Vehicle	Site Operator	0.38
Surface: Ice – Formed From Packed Snow		
Run 2		
TC Blazer	TC Operator	0.18
Site Vehicle	Site Operator	0.16
Surface: Ice – Formed From Packed Snow		
Run 3		
TC Blazer	TC Operator	0.18
Site Vehicle	Site Operator	0.20
Surface: Snow and Bare Patches		
Run 4		
TC Blazer	TC Operator	0.70
Site Vehicle	Site Operator	0.76
Run 5		
TC Blazer	Site Operator	0.72
Site Vehicle	TC Operator	0.79
Surface: Ice		
Run 6		
TC Blazer	TC Operator	0.16
Site Vehicle	Site Operator	0.17
Run 7		
TC Blazer	Site Operator	0.16
Site Vehicle	TC Operator	0.15
CIRCUIT 2		
Surface: 1/8 in. Loose Snow Over Ice		
Run 1		
TC Blazer	TC Operator	0.30
Site Vehicle	Site Operator	0.23
Run 2		
TC Blazer	Site Operator	0.28
Site Vehicle	TC Operator	0.24
Surface: Thin Ice with Bare Patches		
Run 3		
TC Blazer	TC Operator	0.47
Site Vehicle	Site Operator	0.40
Run 4		
TC Blazer	Site Operator	0.39
Site Vehicle	TC Operator	0.33

2.3.2 CRFIs Measured by Transport Canada and Site Systems

These are compared in Figures 2.4 to 2.6. As expected, most CRFIs are in the range of 0.1 to 0.4, as the tests were done on winter surfaces. The following observations can be made:

- The variation between the site and the Transport Canada systems varied from airport to airport. The variation in friction coefficient between a site system and the Transport Canada system ranged from nil to a maximum of 0.09 (i.e., 0.12 versus 0.21, respectively).

  In one case (i.e., Run 5 during Circuit 2 at Airport 3 – Table 2.8), the CRFI variations were similar when the ERDs were switched between the site and the Transport Canada vehicles. This indicates that, for that case, differences in the two vehicles were probably responsible for the observed CRFI variations. More investigation (for more cases) is needed before firm conclusions can be drawn.

- Greater variation was observed between the Transport Canada system and the site systems during Circuit 2. Furthermore, the CRFIs measured by the Transport Canada system were almost always more than those from the site systems for Circuit 2 in contrast to Circuit 1 when a variation was observed. Compare Figures 2.5 and 2.6. This variation should be investigated further. This variation might be due to the following factors:
  (a) a different ERD Mk II was used in Circuit 2 compared to Circuit 1.
  (b) differences in surface conditions, or perhaps less uniformity for the surfaces in Circuit 2 than for Circuit 1. However, it should be noted that all of the tested surfaces were within the range where decelerometers are considered to be reliable, with the possible exception of the tests done at Airport 5 on patchy conditions (with bare pavement showing in places). These tests produced the highest CRFIs measured during the program.

- Generally, the CRFI variation between systems was greater for airports that used the ERD Mk III rather than the ERD Mk II as part of their system. At first glance, Airport 5 appears to be an exception to this statement as relatively large variations were observed at this site, which used the ERD Mk II as part of their system (Table 2.10). However, it should be noted that the largest variations between the TC and the site systems were observed on surfaces with bare pavement patches. These relatively non-uniform surfaces made it difficult to obtain valid comparisons.

- The significance of these CRFI variations needs to be assessed by evaluating their effect on inferred landing distances.

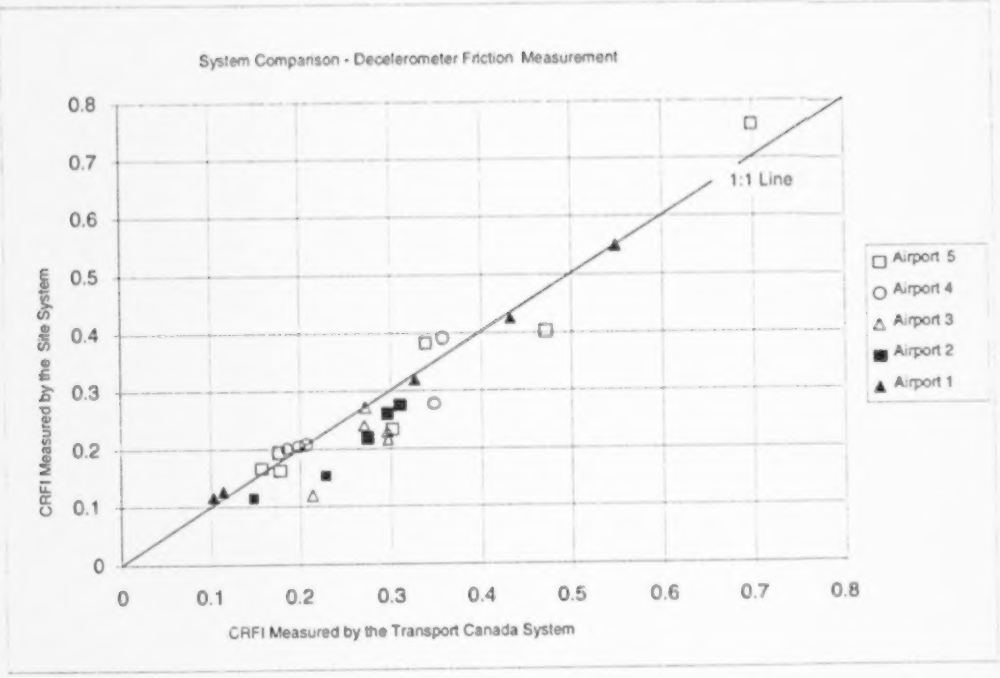


Figure 2.4: CRFIs Measured by TC and Site Systems for Circuits 1 and 2

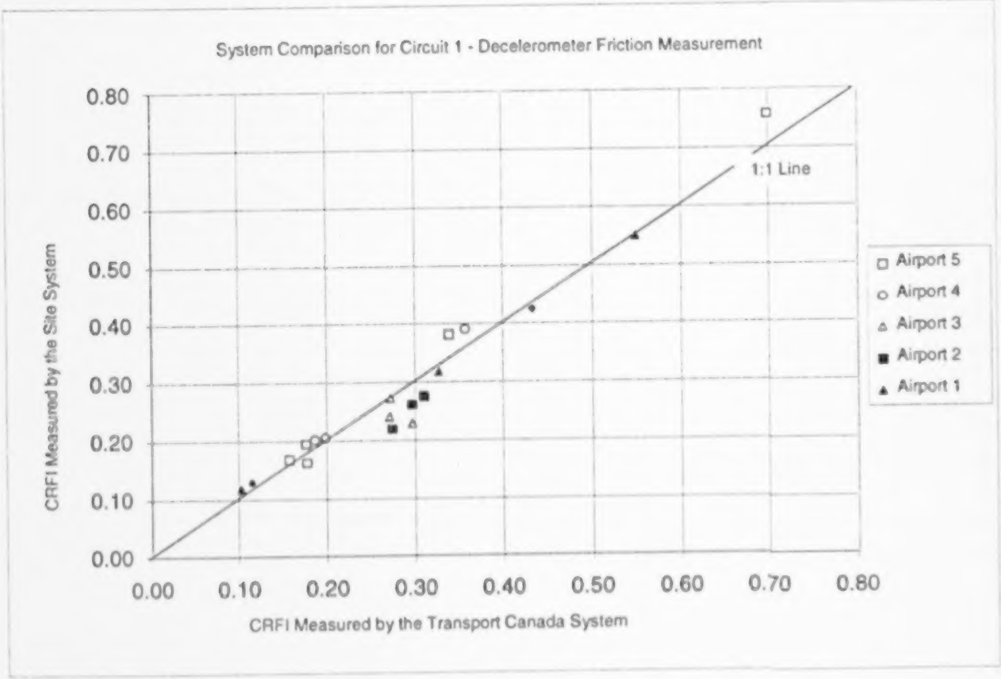


Figure 2.5: CRFIs Measured by TC and Site Systems for Circuit 1

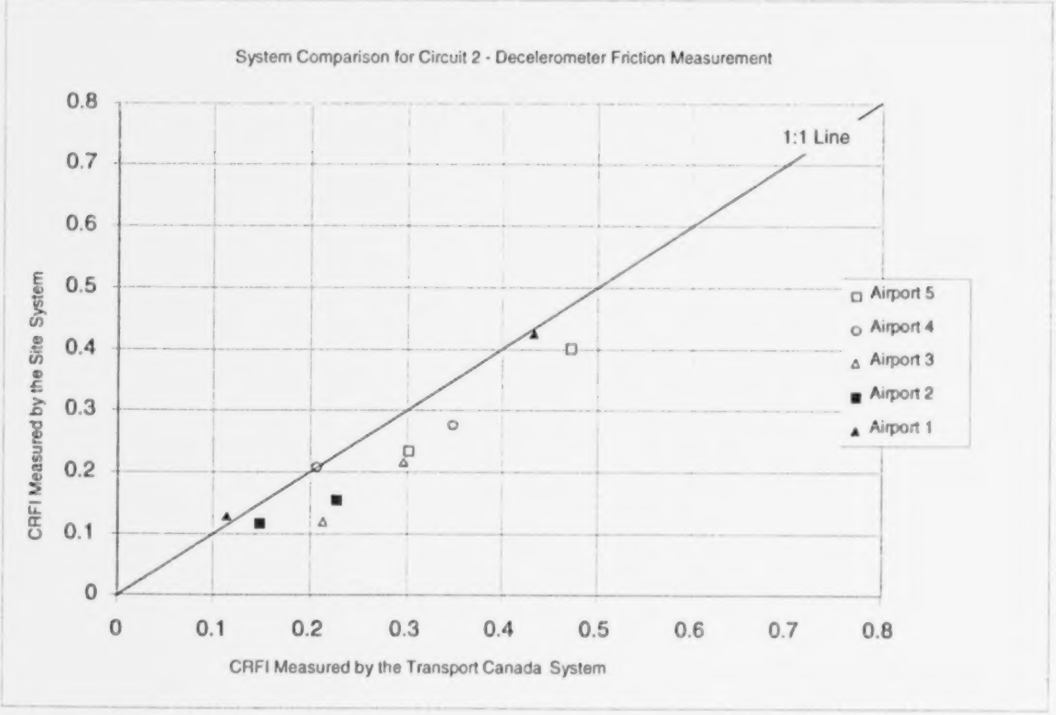


Figure 2.6: CRFIs Measured by TC and Site Systems for Circuit 2

2.3.3 CRFIs Measured with the Operators Switched

Figure 2.7 compares the CRFIs obtained with the operators switched, as follows:

- Transport Canada Blazer and ERD – CRFIs obtained by the TC operator versus those obtained by the sites' operators
- Site vehicle and ERD - CRFIs obtained by the site operator versus those obtained by the TC operator

It is evident that similar CRFIs were obtained with the operators switched. The average CRFI variation was 0.013, with a maximum variation of 0.04. This probably indicates that the operators had all been trained to employ similar measurement techniques. It can be concluded that switching the operators did not affect the CRFI readings significantly, compared to the other differences seen between vehicle-decelerometer pairs.

It should be noted that the data points obtained at Airport 5 on thin ice over bare patches of pavement (Figure 2.7) were not included in the dataset used for these calculations as this surface was relatively non-uniform, which makes it difficult to obtain valid comparisons.

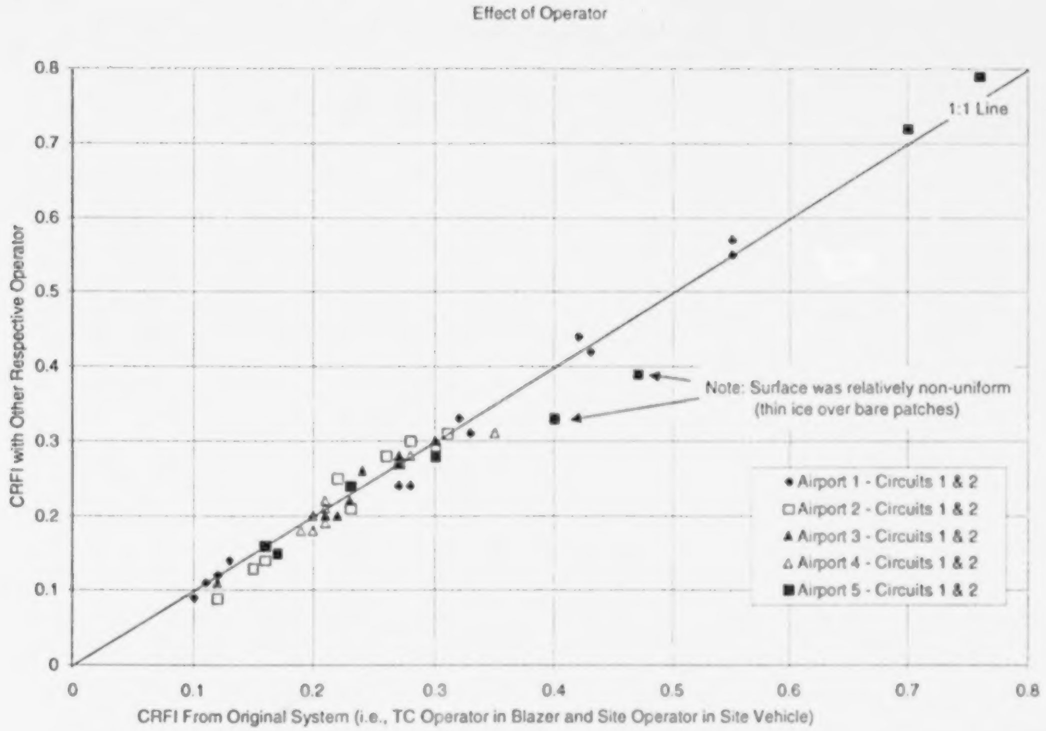


Figure 2.7: CRFIs Measured with the Operators Switched for Circuits 1 and 2

2.3.4 CRFIs Measured with the Operators and Vehicles Switched

Figure 2.8 compares the CRFIs obtained with the operators and vehicles switched, as follows:

- TC Blazer and ERD – operated by the site's operator
- Site Vehicle and ERD – operated by the TC operator

The same trends seen for the system comparison (Section 2.3.2, Figures 2.4 to 2.6) apply to the results with the operators and vehicles switched. The following observations can be made:

- the data show that the Transport Canada system gave CRFIs that were generally equal or higher than the site vehicles, regardless of operator.
- the variations varied from airport to airport. The largest variation was 0.09 (i.e., 0.11 v. 0.20, respectively).
- the significance of the observed CRFI variations needs to be assessed with respect to their effect on inferred landing distances. This is done in Section 2.4.

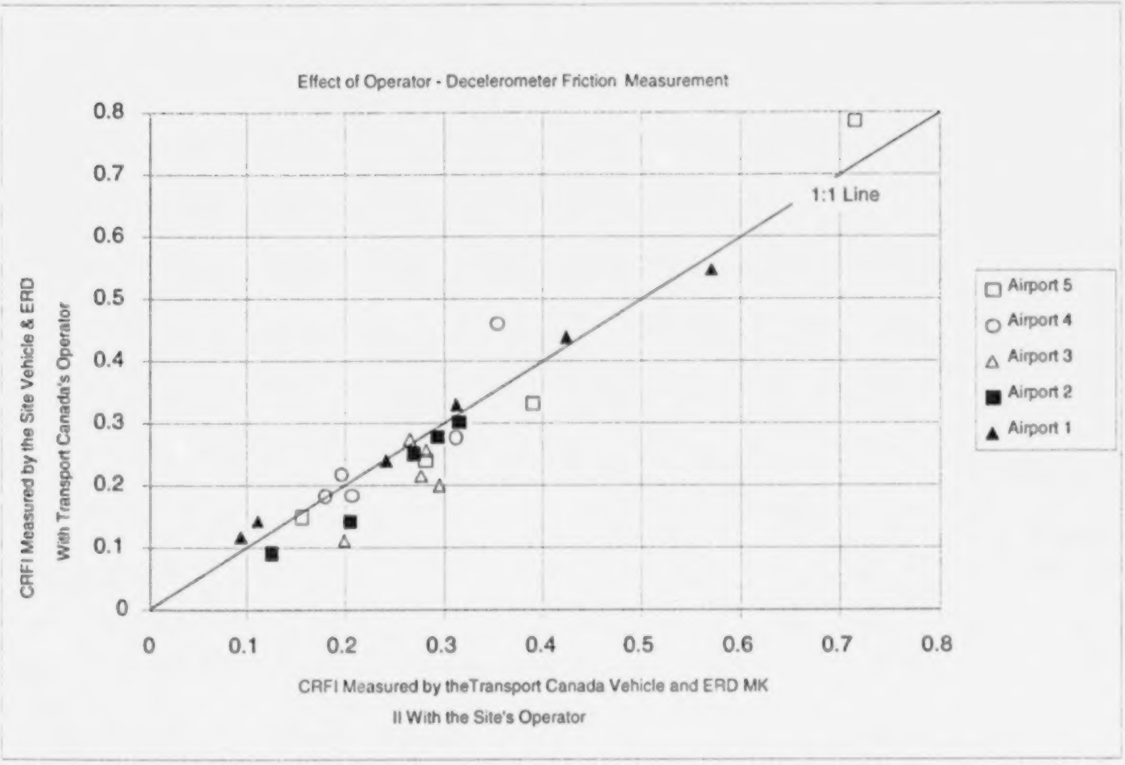


Figure 2.8: CRFIs Measured with the Operators Switched for Circuits 1 and 2

2.4 Inferred Landing Distances from the CRFI Results

2.4.1 Purpose of Analyses

The measured friction coefficients varied somewhat with each airport and circuit. These variations need to be put into perspective to assess their significance.

2.4.2 Analysis Approach

The same approach used during the 2002 project [2] was used again. The Landing Distances (LDs) in the Aeronautical Information Publication (AIP) [3] were used to assess the significance of the observed variations in friction coefficient as they are related to the CRFI. See Figure 2.9.

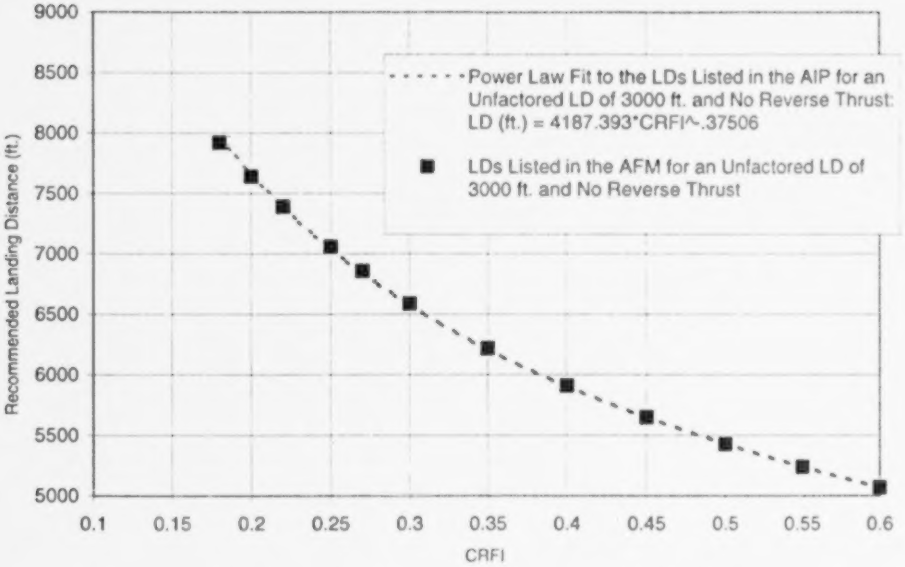


Figure 2.9: Landing Distances in the AIP [3] for No Reverse Thrust

It should be noted that the recommended landing distance increases significantly with decreasing CRFI values. Small decreases in friction coefficient at low CRFIs cause a large increase in landing distance (Figure 2.9). Thus, greater accuracy is required for friction coefficients measured at low CRFIs to maintain the same precision with respect to inferred landing distances.

The analyses were done with respect to an unfactored AIP LD of 914.6 m (3000 ft.), in keeping with the approach used previously [1]. While this provided an evaluation criterion, it should be noted that this is an arbitrary selection, and that the results would vary for other AIP LDs. Unfortunately, further investigation could not be done here, as this was beyond the scope of this project. A more detailed investigation of this issue would be useful.

It should be further noted that the AIP [3] only provides landing distances for CRFIs ranging from 0.18 to 0.60. Consequently, the analyses could only be conducted for CRFIs in this range. Extrapolation would be necessary to infer landing distances for friction coefficients below 0.18. This was not done because information is not available in the AIP to allow reliable extrapolation to landing distances at CRFIs lower than 0.18. Consequently, comparisons with the inferred landing distances could not be done for the whole data set. The test data obtained on lower-friction surfaces were not included in the analyses presented here.

Despite this limitation, the analyses provide a reasonable assessment of the significance of the measured variations in friction coefficient.

Landing distances were inferred for the measured friction coefficients (that were greater than or equal to 0.18) by fitting a power-law curve to the LDs listed in the AIP, as follows:

$$\text{LD (ft.)} = 4187.393 * \text{CRFI}^{-0.37506} \qquad [2.1]$$

Note: The LDs defined by Equation 2.1 are applicable to:

- CRFIs ranging between 0.18 and 0.60 inclusive
- no reverse thrust
- an unfactored LD in the AIP of 3000 ft.

Equation 2.1 was used for all subsequent analyses in this project.

2.4.3 System Comparison: Inferred Landing Distances

The landing distances inferred from the CRFIs measured by the TC System (i.e., the TC Blazer and the TC ERD Mk II, with D. Booth as the operator) are compared with those from the sites' systems in Figure 2.10 and Table 2.11. As expected, consistent differences were not observed; instead, the variations differed among the airports tested.

Table 2.11: System Comparison: Variation Among Airports for Inferred Landing Distances

Range of CRFIs (Measured by the TC ERD Mk II)	Maximum Variation in Inferred Landing Distance[1] (ft.)	Landing Distance from the AIP (ft.) for Indicated CRFIs	% Variation[1] in Inferred Landing Distance w/r to the indicated AIP LD
0.18 to 0.25	251	0.2 CRFI: 7660	3.3
>0.25 to 0.35	-826	0.3 CRFI: 6580	-12.6
>0.35 to 0.45	209	0.4 CRFI: 5900	3.5
>0.45 to 0.55	2[2]	0.5 CRFI: 5430	0.0[2]
>0.55	146[2]	0.6 CRFI: 5070	+2.9[2]

1. Positive or negative variations indicate that the LD inferred from the TC System (i.e., the TC Blazer, and ERD MK II, with D. Booth as the operator) was longer or shorter than the LD inferred from the site system, respectively.
2. Only one data point.

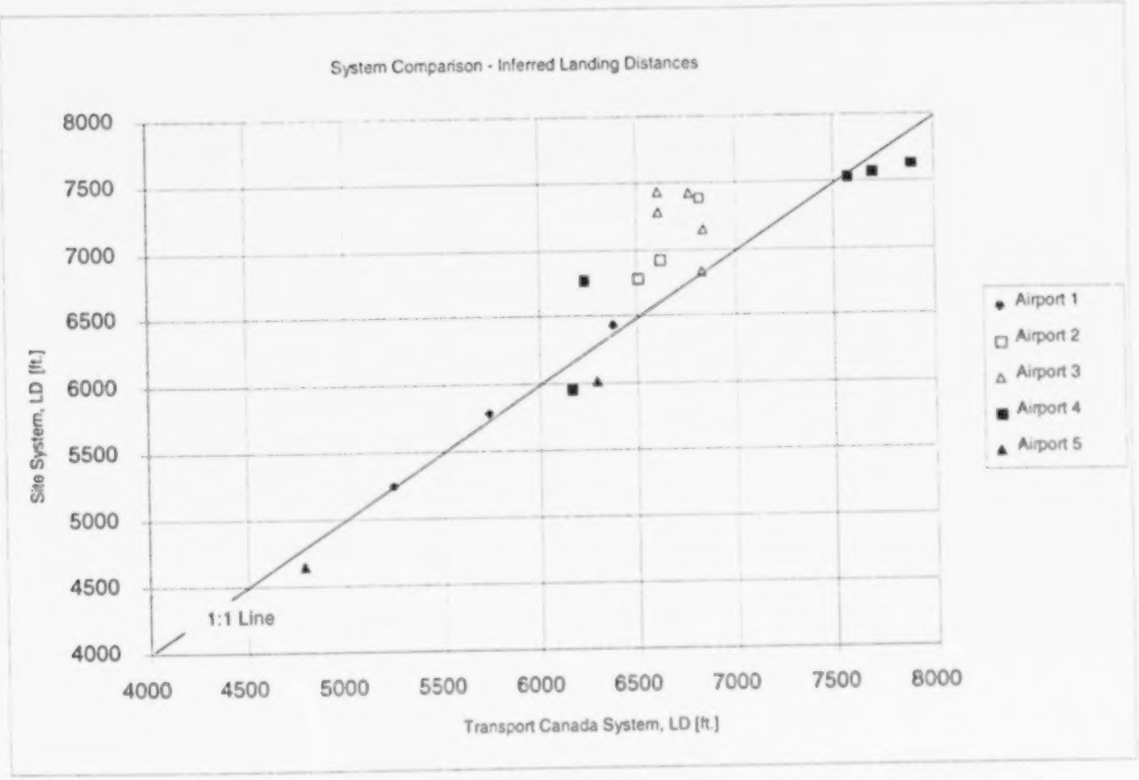


Figure 2.10: Inferred Landing Distance Comparison for the CRFI Systems

In most cases, the LDs inferred from the sites' systems were more than those from the TC system (Figure 2.10 and Table 2.11). The maximum variation in landing distance was 826 ft. with the site system indicating a longer landing distance than the TC system (Table 2.11).

The distribution of inferred landing distance variations was investigated to assess the severity of maximum observed value (of 826 ft.). As expected, more small landing distance variations were observed than large ones (Figure 2.11).

It is of interest to evaluate whether the maximum observed value (of 826 ft.) is a single, extreme isolated point, or rather, a maximum that was sampled from a relatively uniform distribution. As thirty percent of the observed landing distance variations exceeded 500 ft. (Figure 2.12), the latter is believed to be the case.

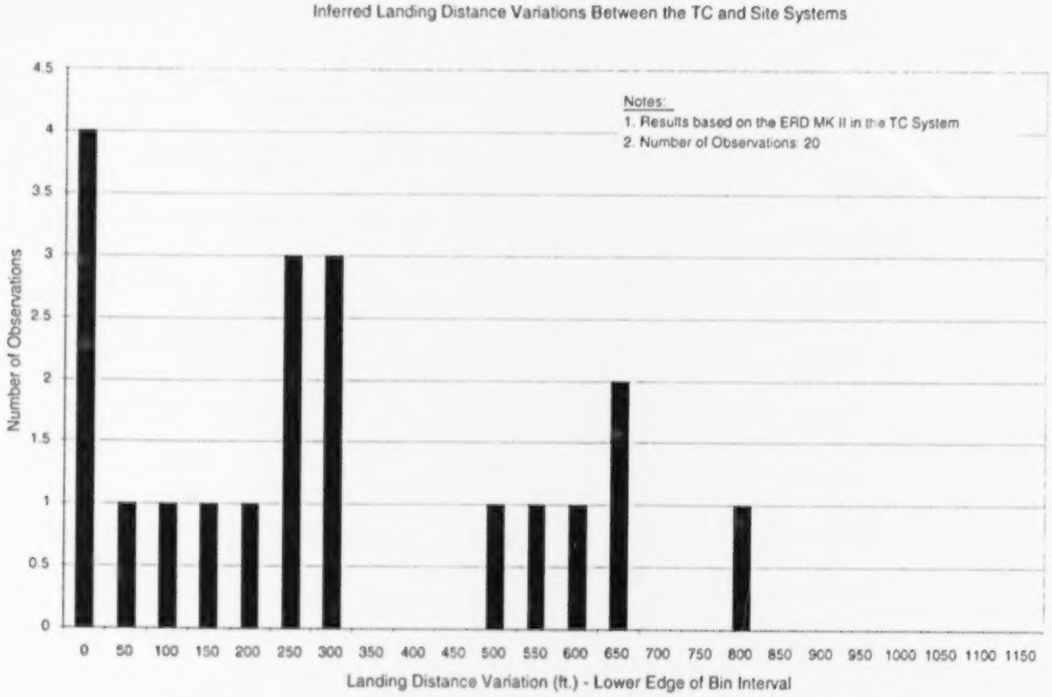


Figure 2.11: Histogram of Inferred Landing Distance Variations

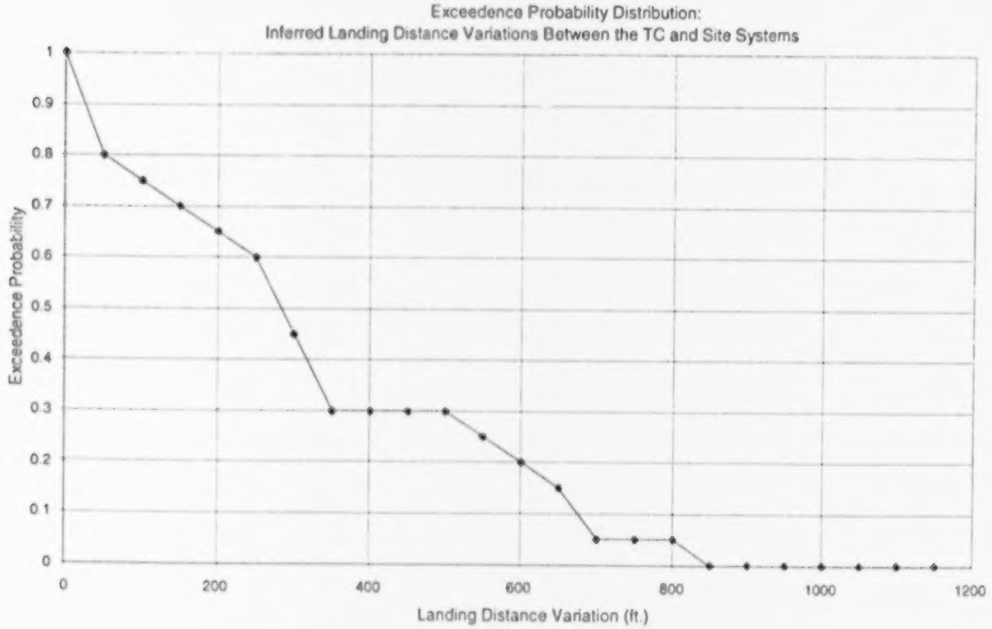


Figure 2.12: Exceedence Probabilities for Inferred Landing Distance Variations

2.4.4 Effect of Operator on Inferred Landing Distances

The landing distances inferred by switching the vehicle operators are compared in this section. Figure 2.13 compares the LDs inferred from the CRFIs measured by the following systems:

- the TC Blazer, the TC ERD Mk II, and the site's operator; and
- the site's vehicle, the site's ERD, with D. Booth as operator.

The maximum variation in inferred landing distance was 1,039 ft., with the site system indicating a longer landing distance than the TC system (Table 2.12).

Consistent differences were not observed as the variations differed among the airports tested. This variation is similar to that observed for the system comparisons (presented in Section 2.4.3, Figure 2.13 and Table 2.12). As was stated previously (in Section 2.3), this indicates that the operator is not the major source of the differences among the CRFIs observed at the airports.

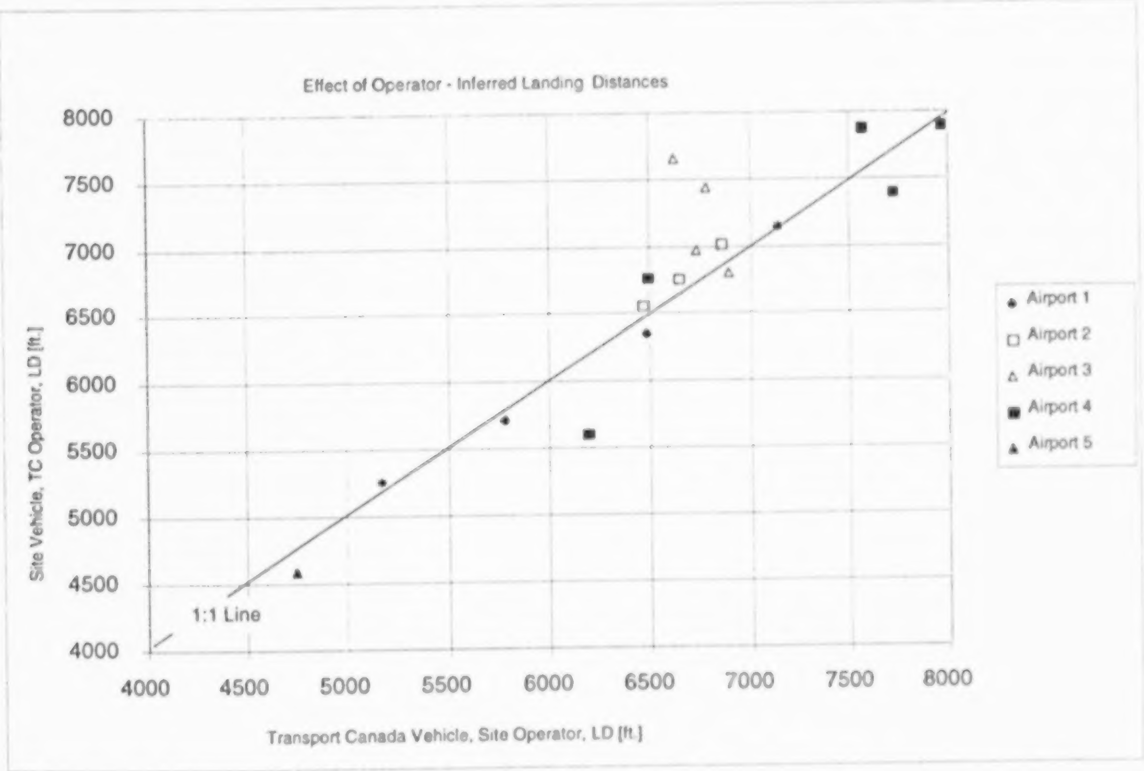


Figure 2.13: Comparison with Operators Switched: Inferred Landing Distances

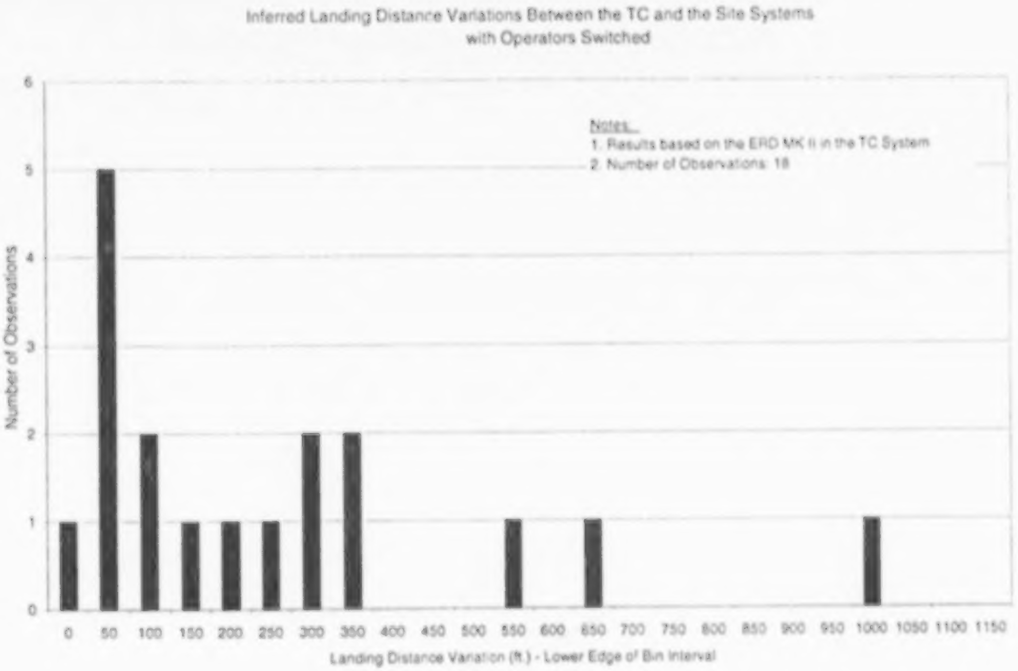
**Table 2.12: Comparison with Operators Switched:
Variation among Airports for Inferred Landing Distances**

Range of CRFIs (Measured by the TC ERD Mk II)	Maximum Variation in Inferred Landing Distance[1] (ft.)	Landing Distance from the AIP (ft.) for Indicated CRFIs	Percent Variation[1] in Inferred Landing Distance with Respect to the AIP LD
0.18 to 0.25	-318	0.2 CRFI: 7660	-4.2
>0.25 to 0.35	-1039	0.3 CRFI: 6580	-15.8
>0.35 to 0.45	589	0.4 CRFI: 5900	10.0
>0.45 to 0.55	No data	0.5 CRFI: 5430	No data
>0.55	165	0.6 CRFI: 5070	+3.3

1. Positive or negative variations indicate that the LD inferred from the system comprised of the TC Blazer, the ERD MK II, and the site's operator was longer or shorter than the LD inferred from the site system with D. Booth operating it, respectively.

The distribution of inferred landing distance variations was investigated to assess the severity of maximum observed value (of 1039 ft.). As expected, more small landing distance variations were observed than large ones (Figure 2.14).

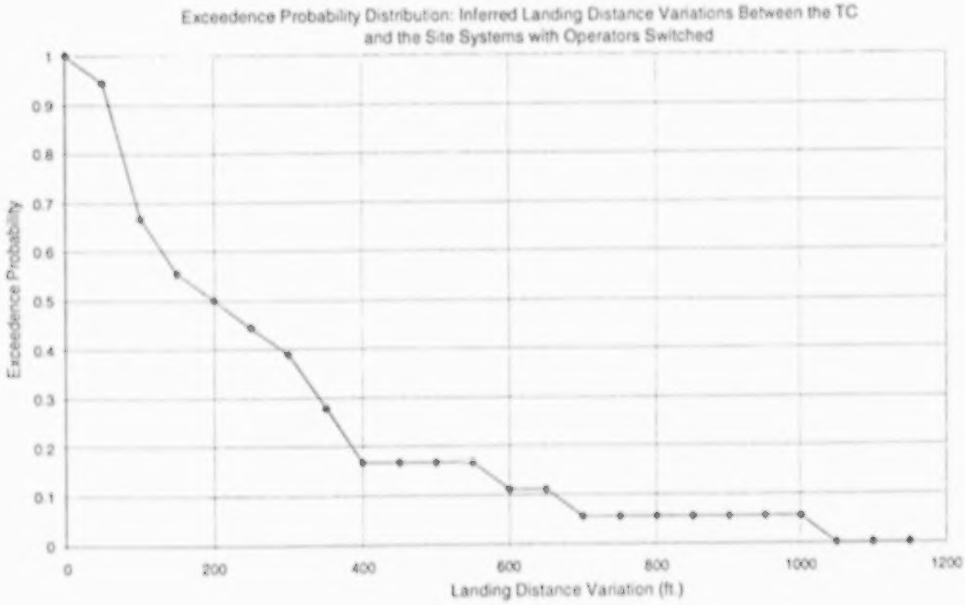
It is of interest to evaluate whether the maximum observed value (of 1039 ft.) is a single, extreme isolated point, or rather, a maximum that was sampled from a relatively uniform distribution. As fifteen percent of the observed landing distance variations exceeded 500 ft. (Figure 2.15), the latter is believed to be the case.



Inferred Landing Distance Variations Between the TC and the Site Systems
with Operators Switched

Notes:
1. Results based on the ERD MK II in the TC System
2. Number of Observations: 18

Figure 2.14: Histogram of Inferred Landing Distance Variations



Exceedence Probability Distribution: Inferred Landing Distance Variations Between the TC
and the Site Systems with Operators Switched

Figure 2.15: Exceedence Probabilities for Inferred Landing Distance Variations

3. EFFECT OF ABS ON OR OFF

3.1 Objectives

Tests were conducted in 2002 [1] which showed that the friction coefficients measured by decelerometers were not greatly affected by whether or not the vehicle's ABS system was disabled or not. These tests were principally done with the ERD Mk II and the ERD Mk III in the TC Blazer and a ½-ton pickup truck, although a few tests were done with other vehicles and decelerometers.

The objectives of this test program were to investigate this finding further by expanding the information base. The program was aimed at obtaining:

- data for a wider range of vehicles: six generic types of vehicles were tested;
- a broader database for each decelerometer type – the ERD Mk II, the ERD Mk III, the Bowmonk, and the Tapley were tested; and
- data for a wide range of winter surfaces.

3.2 Test Method and Scope

3.2.1 Test Location and Dates

All tests were conducted at Jack Garland Airport in North Bay, Ontario. The tests were conducted from February 24 to February 27 inclusive.

3.2.2 Test Vehicles

Eight vehicles were tested, as summarized below:

- a sport utility vehicle (termed the Blazer – Figure 3.1)
- three ½-ton pickup trucks, as listed below. Most of the tests were done with the 4x4 ½-ton. As the results with the other ½-ton trucks did not vary greatly, all results obtained with the ½-ton trucks were grouped together under the generic term half-ton. However, the results obtained with each vehicle were identified separately in plotting the results.
  - a 4x4 Chevrolet ½-ton truck (termed the 4x4 ½-ton, Figure 3.2)
  - a 2x4 Ford ½-ton truck (termed the 2x4 ½-ton, Figure 3.3)
  - a 4x4Dodge ½-ton truck from Windsor airport (termed the 4x4 Windsor Truck, Figure 3.4)

- a ¾-ton pickup tuck (termed the three-quarter-ton, Figure 3.5)
- a 1-ton truck (termed the one-ton, Figure 3.6)
- a rear wheel drive full-size car (termed the Rear Wheel Drive (RWD) Car, Figure 3.7)
- a front wheel drive full-size car (termed the Front Wheel Drive (FWD) Car, Figure 3.8)

Detailed information regarding these vehicles is provided in Tables 3.1 and 3.2.

Table 3.1: Vehicle Information

Name Used in Report	TC Blazer	4x4 ½-Ton	2x4 ½-Ton	Windsor ½-Ton	¾-Ton	1-Ton	FWD car	RWD car
Vehicle – General								
Manufacturer	Chevrolet	Chevrolet	Ford	Dodge	Chevrolet	Ford	Chrysler	Ford
Model	Blazer	½-Ton - 4x4	½-Ton - 2x4	Ram 1500	¾-Ton 4x4	1-Ton 4x4	Intrepid FWD	Crown Victoria
Year	1991	2003	2002	2003	2003	2002	2003	2003
Odometer [km]	114,421	4,486	16,399	27	30	4,440	15,048	1,046
Wheelbase [m]	2.72	3.65	3.53		4.00	4.19	2.87	2.92
Vehicle - Antilock Braking System (ABS)								
Type	4 wheel	4 wheel	4 wheel		4 wheel	4 wheel	4 wheel	4 wheel
Vehicle – Tires								
Tire size	P235/75R15	265/75R16	235/70R16	P245/70 R17	245/75R16	225/70R19.5	225/60 R16	225/60 R16
Tire brand	Michelin	Good Year	BF Goodrich	Michelin	Firestone radial	General	Eagle GoodYear	GoodYear
Tire type (season)	M + S	AT/S All season	All season	LT x All Season	A/T All season	LMT All season	All season	All season
Tire pressure psi (kPa)	35 (240)	41 (280)	35 (240)	35 (240)	55 (380)	75 (517)	32 (220)	35 (240)
Tread depth [mm]	9	9	9	9	15	13	9	9

Table 3.2: Vehicle Weight and Tire Contact Pressure

Vehicle - General							
Manufacturer	Chevrolet	Chevrolet	Ford	Chevrolet	Ford	Chrysler	Ford
Model	Blazer	½-Ton 4x4	½-Ton 2x4	¾-Ton 4x4	1-Ton 4x4	Intrepid FWD	Crown Victoria RWD
Weight of Vehicle [lb.]							
Vehicle [lbs]	4260	5745	5810	7260	9230	3830	4630
Weight Per Tire [lb.]							
Front Passenger	1050	1415	1310	1730	2300	860	1260
Front Driver	1260	1780	1710	2520	2310	1340	1260
Rear Passenger	1060	1300	1430	1650	2330	850	960
Rear driver	890	1250	1360	1360	2290	780	1150
Weight per Tire [kN]							
Front Passenger	4.670	6.294	5.827	7.695	10.230	3.825	5.604
Front Driver	5.604	7.917	7.606	11.209	10.275	5.960	5.604
Rear Passenger	4.715	5.782	6.361	7.339	10.364	3.781	4.270
Rear driver	3.959	5.560	6.049	6.049	10.186	3.469	5.115
Tire Print Contact Area[1] [mm^2]							
Front Passenger	13,548	14,718	15,000	14,637	17,681	12,198	13,095
Front Driver	15,927	17,581	14,879	18,347	16,935	15,040	11,996
Rear Passenger	11,915	11,189	16,573	9,839	10,302	11,673	10,161
Rear driver	10,927	10,927	17,258	10,000	9,698	7,984	9,032
Tire Surface Pressure[2] [mPa]							
Front Passenger	0.345	0.428	0.388	0.526	0.579	0.314	0.428
Front Driver	0.352	0.450	0.511	0.611	0.607	0.396	0.467
Rear Passenger	0.396	0.517	0.384	0.746	1.006	0.324	0.420
Rear driver	0.362	0.509	0.351	0.605	1.050	0.435	0.566
Total Vehicle Surface Contact Pressure[3] [kPa]							
	362	470	406	611	752	363	465

Note:

1. This was defined as: the overall footprint area less the area of the grooves not in contact with the surface.
2. This was defined as: Weight on Tire/Tire Print Contact Area
3. This was defined as: Total Vehicle Weight/Total Tire Contact Area (i.e., for all four tires)
4. The above weights do not include the weight of the operator.

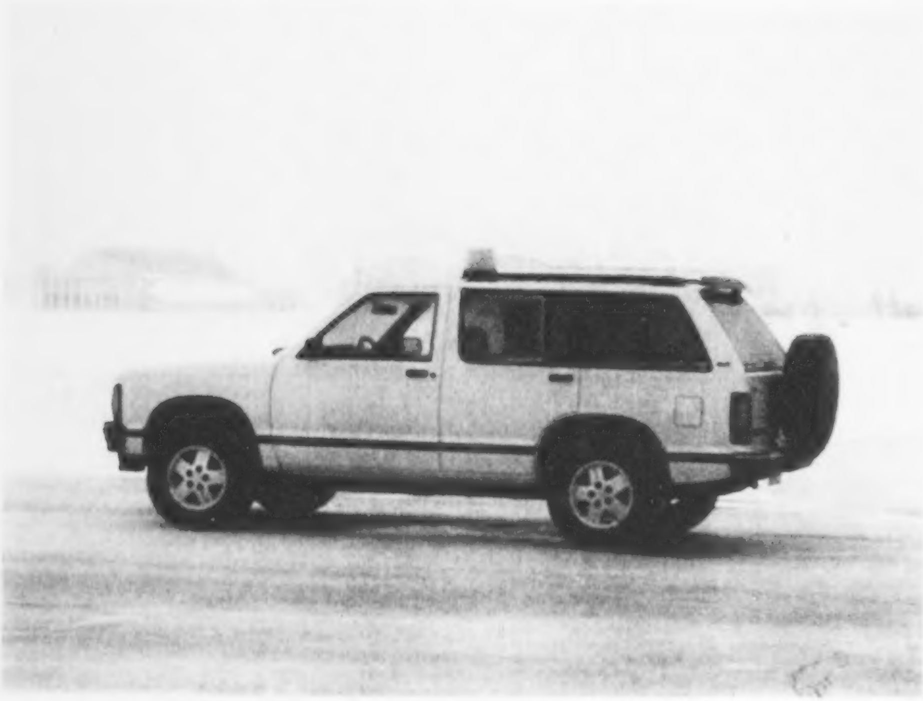


Figure 3.1: The Blazer

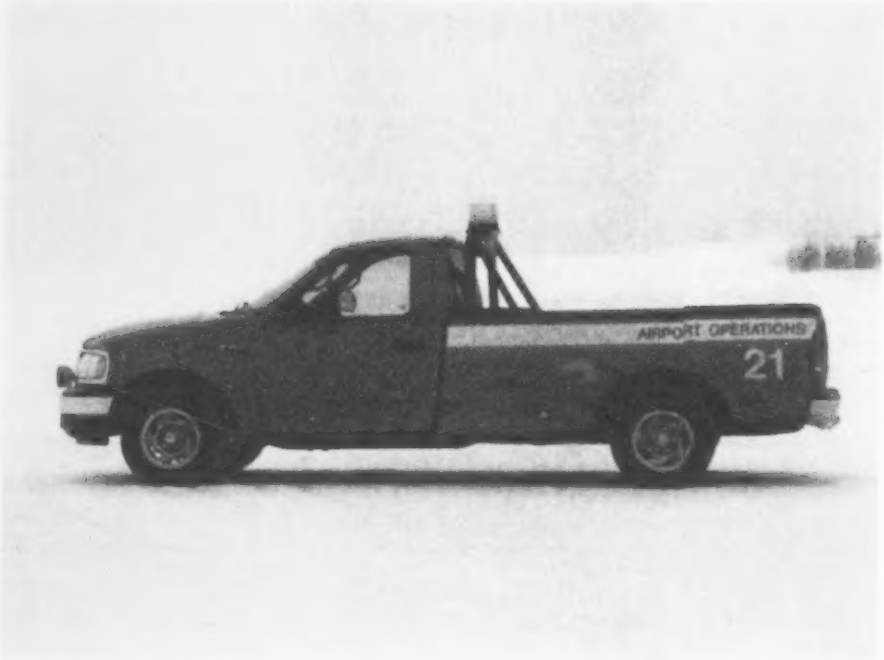

AIRPORT OPERATIONS
21

Figure 3.2: The 2x4 Ford ½-Ton Truck

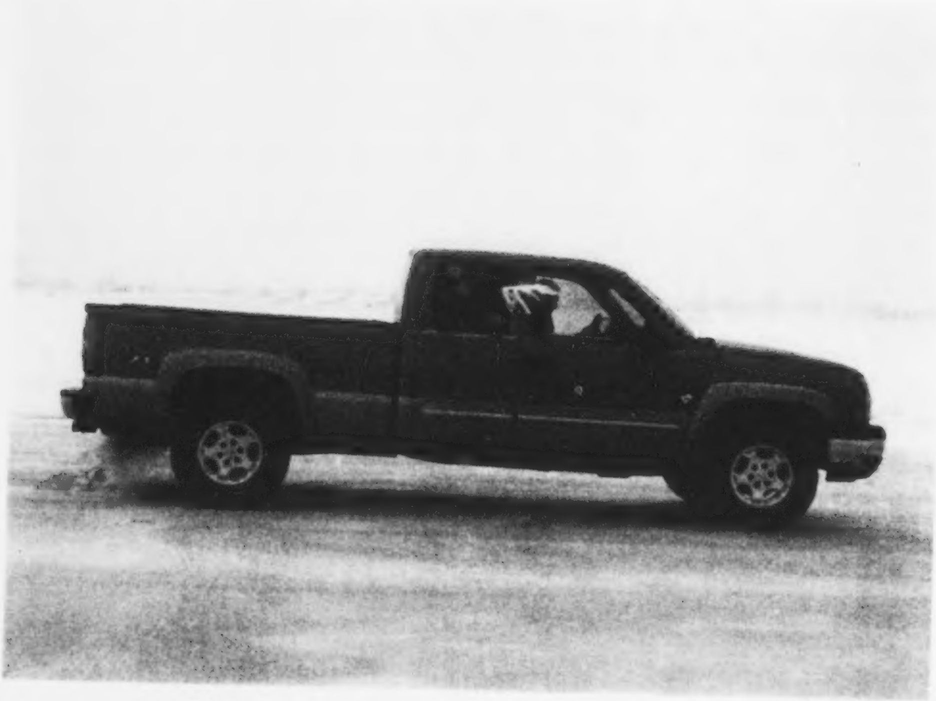


Figure 3.3: The 4x4 Chevrolet ½-Ton Truck

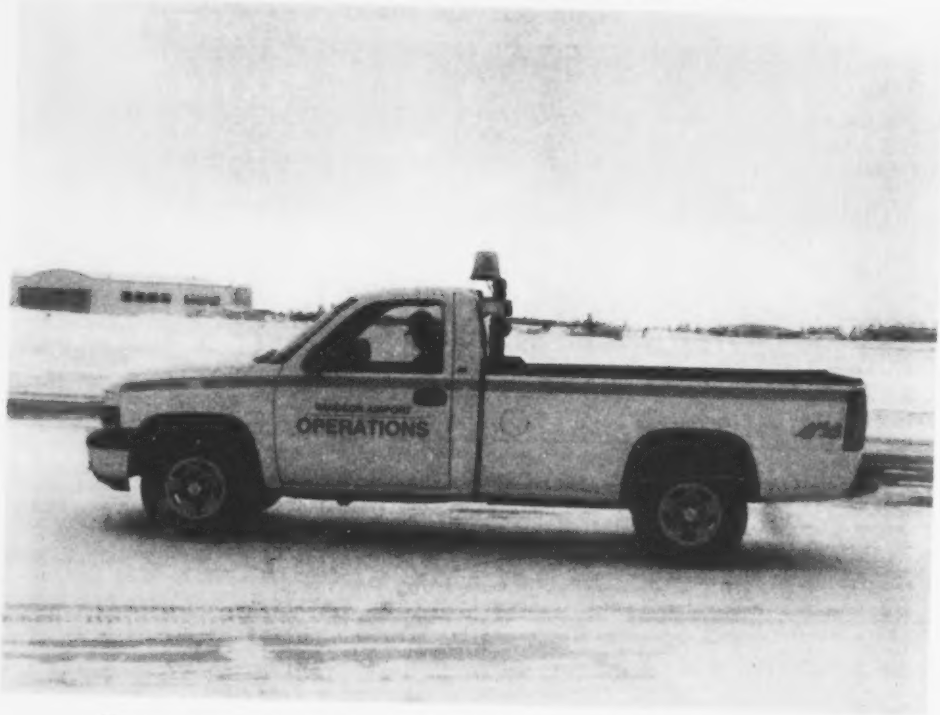

WINDSOR AIRPORT
OPERATIONS
4x4

Figure 3.4: The Dodge 4x4 Windsor Airport ½-Ton Truck

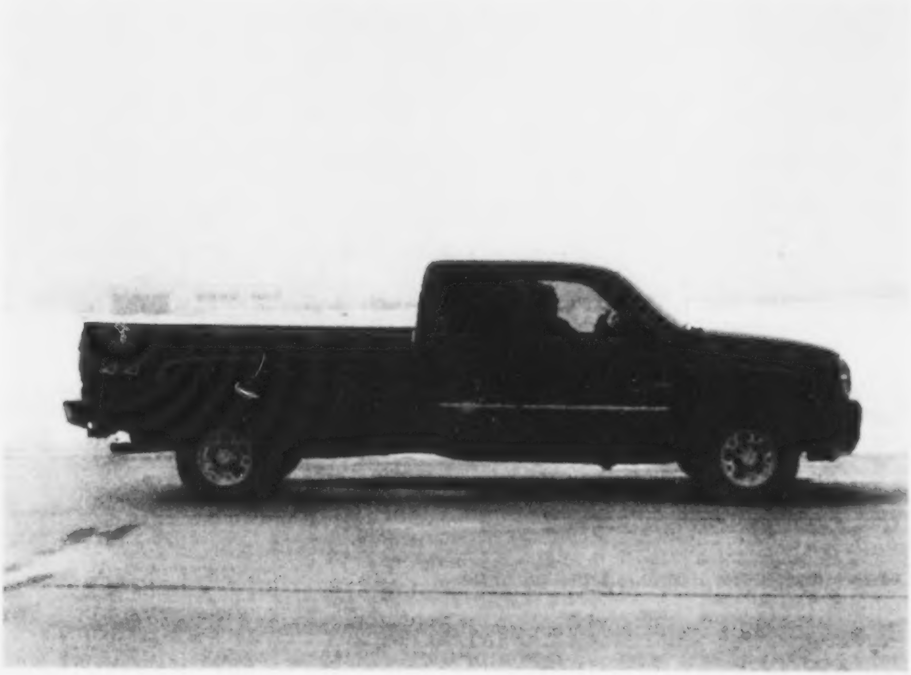


Figure 3.5: The ¾-Ton Truck

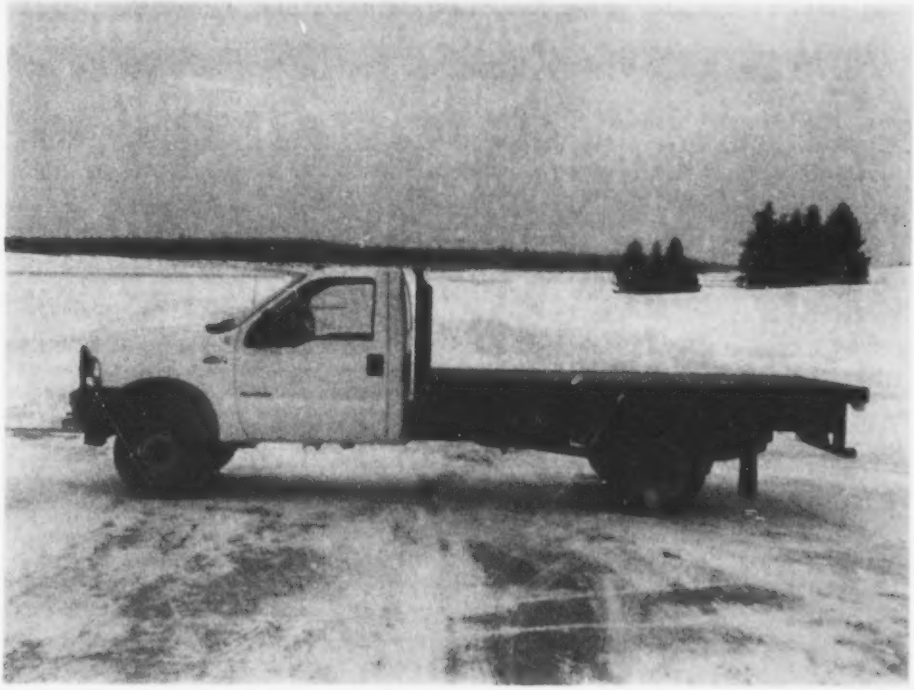


Figure 3.6: The 1-Ton Truck

Figure 3.7: The RWD Car

Figure 3.8: The FWD Car

3.2.3 Decelerometers Used

Four types were tested, as listed below and summarized in Table 3.3:

- Mk III Electronic Recording Decelerometer (ERD)
- Mk II Electronic Recording Decelerometer (ERD)
- Electronic Tapley model BR 500 decelerometer
- Electronic Bowmonk model AMF2 decelerometer

All four decelerometers were mounted on one metal plate that was moved from vehicle to vehicle.

Table 3.3: Decelerometers used for the ABS Tests

Decelerometer Model	ERD Mk II	ERD Mk III	Bowmonk AFM 2	Tapley BR 500
Serial No.	219	24	i12136	97001
Date of Last Calibration	• Nov. 2002 • Recalibrated in Jan. 2003 (Section 2)	• Sept. 2002 • Recalibrated in Jan. 2003 (Section 2)	• Nov. 26, 2002 • Jan. 9, 2003 (internal calibration)	Sept. 11, 2002

At the request of A. Cormier of Bowmonk (who was onsite for some tests), the Bowmonk was tested in two configurations as follows:

- Average – the Bowmonk records average friction coefficients in this configuration. It was used in this mode for tests prior to the afternoon of February 25. This data set is comprised of test numbers 77 to 81, for the Bowmonk. (It was not tested on February. 24, as it was not available on that date). See Section 3.2.5 for a detailed test matrix.

- Peak – the Bowmonk records the peak friction coefficient in this configuration. It was used in this mode for all tests after the morning of February 25. This data set is comprised of all test numbers except 77 to 81, where it was used in the average configuration. See Section 3.2.5 for a detailed test matrix.

The "peak" and "average" data were separated out on all plots that were made.

3.2.4 Test Surfaces and Environmental Conditions

The following surfaces were tested. Detailed test matrices are provided in Section 3.2.5.

- Bare ice (Figures 3.9 and 3.10) – this was formed by flooding. Tests were done on bare ice on February 24 and February 26.
- Loose snow on pavement (Figures 3.11 and 3.12) – the depth of the loose snow ranged from 3 to 9 mm (1/8 in. to 3/8 in.). This surface was tested on February 24, February 25, and February 27.
- Loose snow on compacted snow (Figures 3.13 to 3.14) - the depth of the loose snow was 6 mm (¼ in.). This surface was tested on February 26 and February 27.
- Partly compacted, sanded snow on pavement (Figures 3.15 to 3.16) - This surface was 1/8 in. snow that had been partly compacted by traffic on pavement. It had been plowed but not swept, and sanded twice. It was tested on February 25.

Environmental conditions for each test day are summarized in Table 3.4.

Table 3.4: Temperature and Wind Conditions

Date	Time	Temperature (°C)		Date and Time	Wind	
		Air	Surface		Speed	Direction
24-Feb.	9:17	-21	-17	24-Feb.	6	E
24-Feb.	1:39	-16	-13	24-Feb.	2	NW
25-Feb.	8:49	-20	-21	25-Feb.	2	S
25-Feb.	1:25	-14	-14	25-Feb.	8	SW
26-Feb.	10:09	-14	-15	26-Feb.	7	SW
26-Feb.	2:55	-11	-10	26-Feb.	15	SW
27-Feb.	9:47	-9	-4	27-Feb.	5	S
27-Feb.	10:01	-9	-9	27-Feb.	5	SW

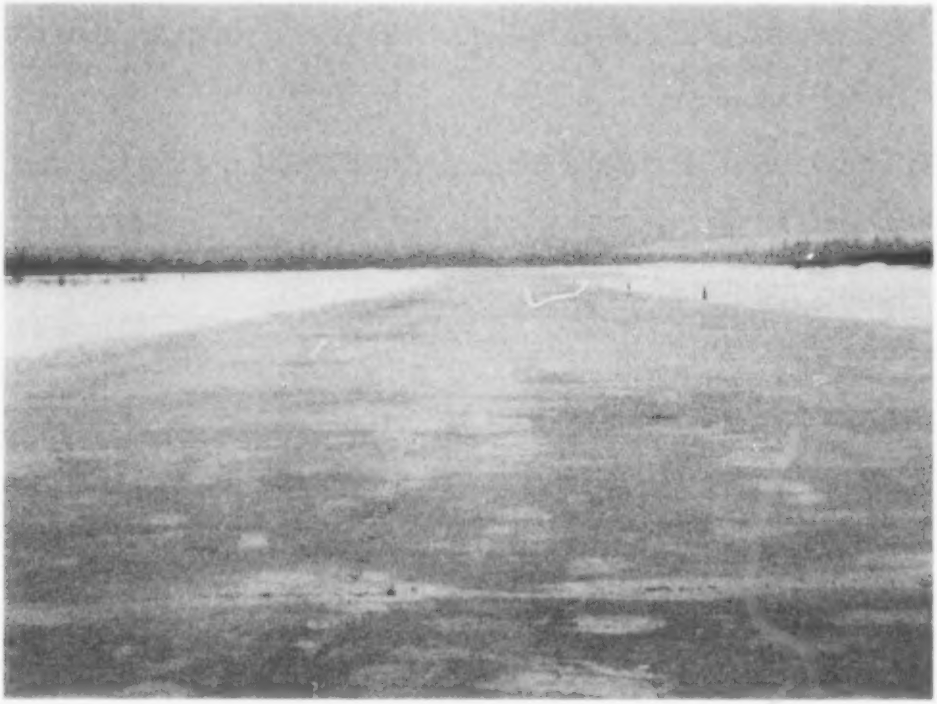


Figure 3.9: Ice Surface

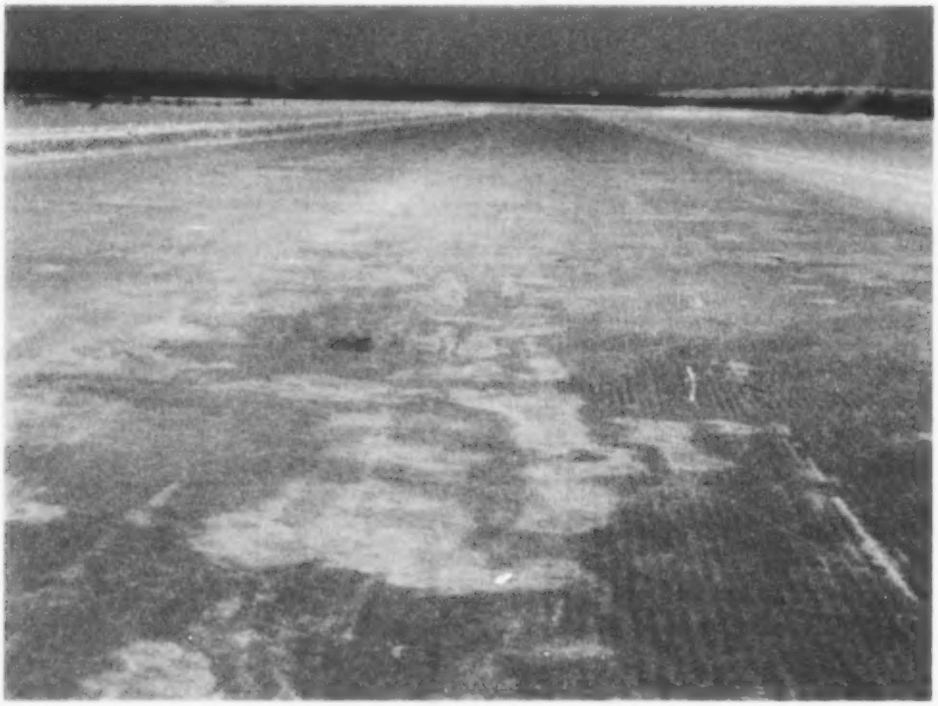


Figure 3.10: Ice Surface

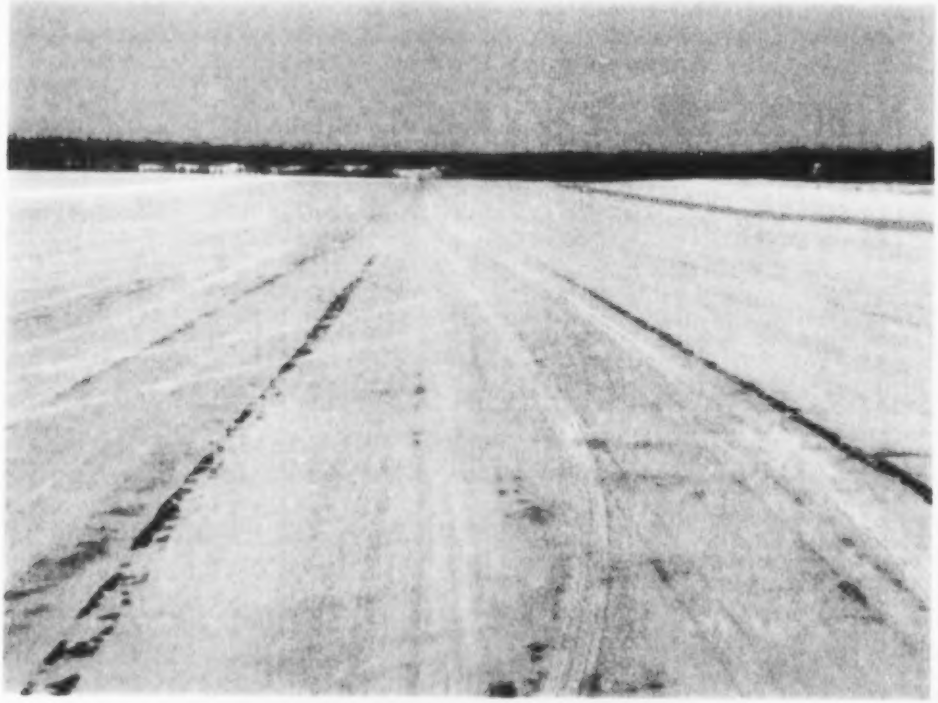


Figure 3.11: Loose Snow on Pavement

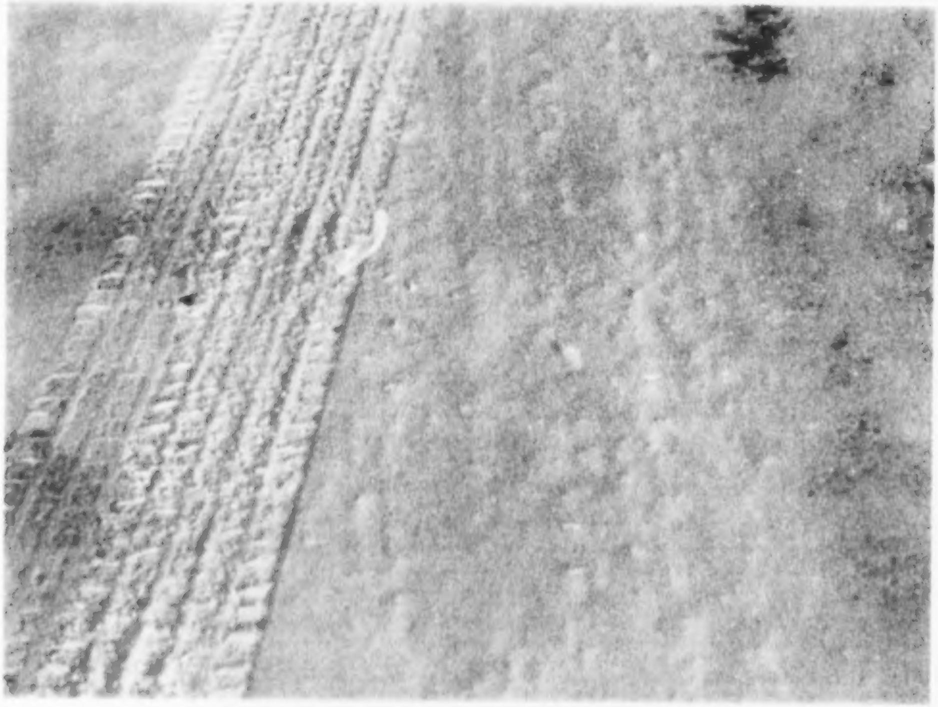


Figure 3.12: Loose Snow on Pavement

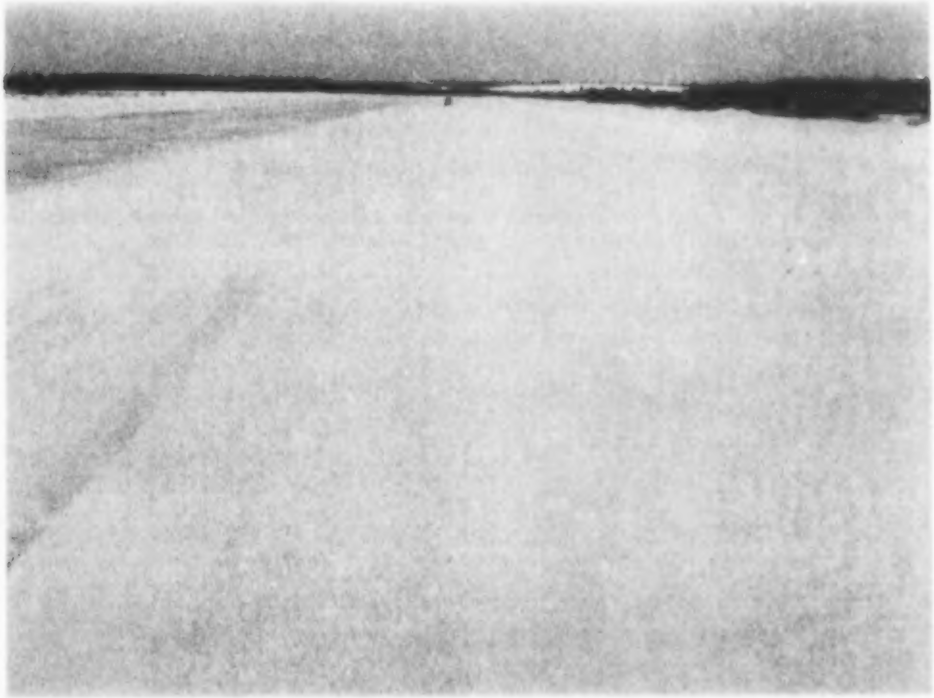


Figure 3.13: Loose Snow on Packed Snow

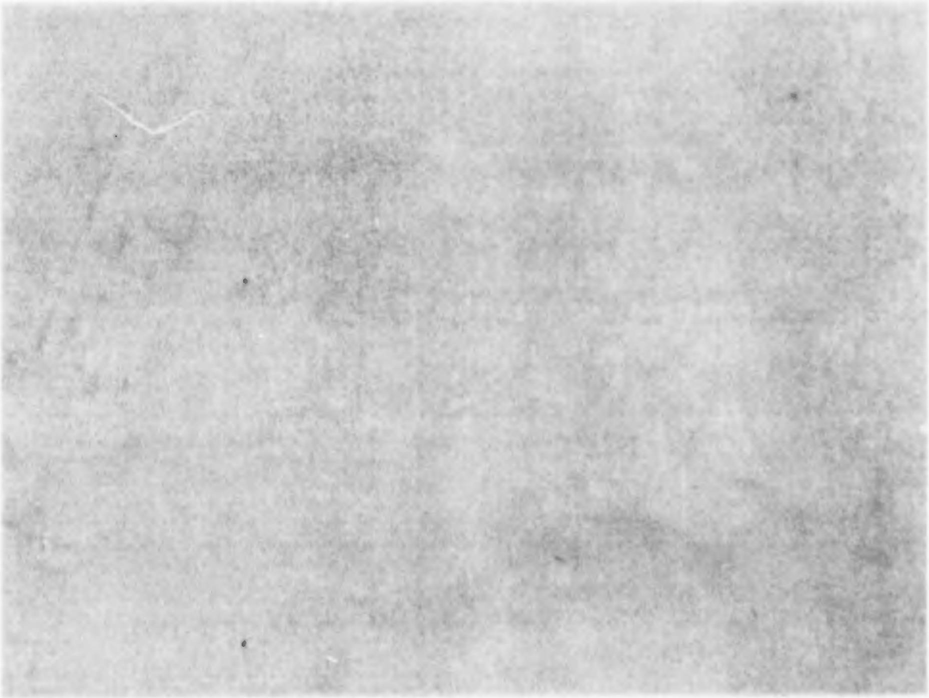


Figure 3.14: Loose Snow on Packed Snow

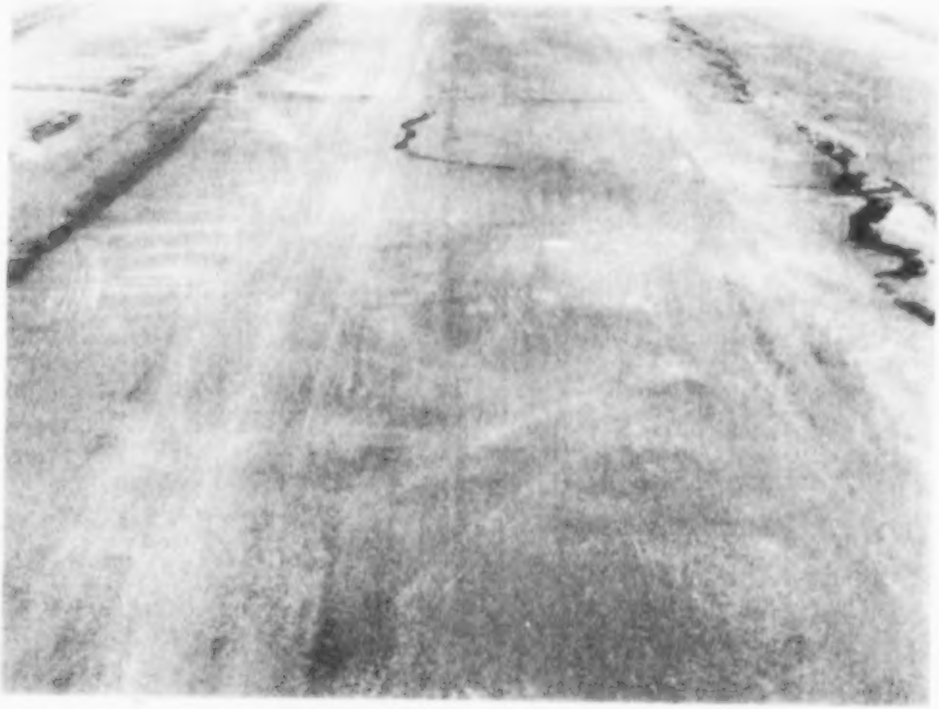


Figure 3.15: Sanded Partly Consolidated Snow on Pavement

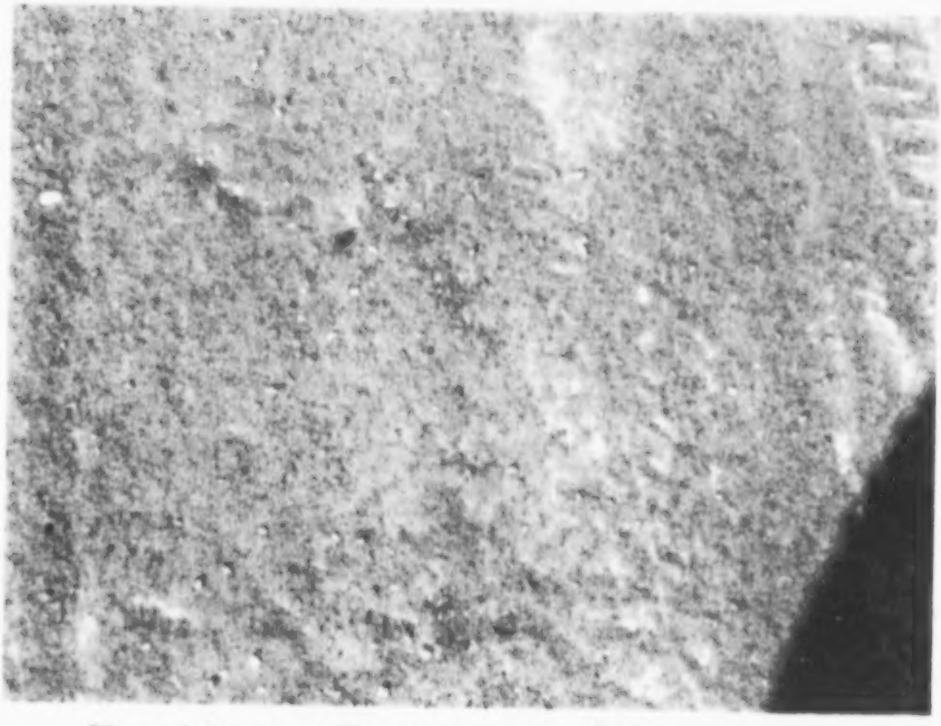


Figure 3.16: Sanded Partly Consolidated Snow on Pavement

3.2.5 Test Matrix

The test matrix is listed in Tables 3.5 to 3.8 for February 24 to February 27 respectively. A total of 101 tests were carried out. The following parameters were varied:

- whether the vehicle's ABS system was disabled or not;
- the vehicle type; and
- the surface condition.

The following parameters were held constant:

- the vehicle operator – all tests were done by D. Booth, from North Bay airport; and
- the vehicle speed – all tests were done at 50 km/h.

Table 3.5: Test Matrix: February 24 Tests

Test	Date	Surface	Vehicle / Time	ABS	Decelerometers Used				Comments
No.				On/Off	Mk 2	Mk 3	Bomonk	Tapley	
1	24-Feb.	Ice Lane A	Blazer 9:17	Off	√	√			Reference Run ABS Off Lanes A Test 1
1	24-Feb.	Ice Lane B	Blazer 9:21	Off	√	√			Reference Run ABS Off Lanes B Test 1
1	24-Feb.	Ice Lane C	Blazer 9:24	Off	√	√			Reference Run ABS Off Lanes C Test 1
2	24-Feb.	Ice Lane A	Blazer 9:32	On	√	√			ABS On 2WD Lane A Test 2
3	24-Feb.	Ice Lane A	Blazer 9:41	Off	√	√			ABS Off 2WD Test 3 Lane A
4	24-Feb.	Ice Lane B	½-Ton 4x4 10:15	Off	√	√		√	ABS Off 2WD Test 4 Lane B
5	24-Feb.	Ice Lane B	½-Ton 4x4 11:10	On	√	√		√	ABS On 2WD Test 5 Lane B
5A	24-Feb.	Ice Lane B	½-Ton 4x4 11:15	On	√	√		√	ABS On 4WD Test 5A Lane B
6	24-Feb.	Ice Lane C	¾-Ton 4x4 11:41	On	√	√			ABS On 2WD Test 6 Lane C
6A	24-Feb.	Ice Lane C	¾-Ton 4x4 11:51	On	√	√			ABS On 4WD Test 6A Lane C
7	24-Feb.	Ice Lane C	¾-Ton 4x4 12:00	Off	√	√			ABS Off 2WD Test 7 Lane C
51	24-Feb.	1/4 in. Loose Snow On	½-Ton 4x4 13:39	On		√			ABS On 2WD Test 51 East of centre line
52	24-Feb.	1/4 in. Loose Snow On	½-Ton 4x4 13:45	On	√	√			ABS On 2WD Test 52 East of centre line
53	24-Feb.	1/4 in. Loose Snow On	½-Ton 4x4 13:52	On	√	√			ABS On 4WD Test 53 East of centre line
54	24-Feb.	1/4 in. Loose Snow On	½-Ton 4x4 14:00	Off	√	√			ABS Off 2WD Test 54 East of centre line
55	24-Feb.	1/4 in. Loose Snow On	Blazer 14:15	On	√	√			ABS On 2WD Test 55 West of centre line
56	24-Feb.	1/4 in. Loose Snow On	Blazer 14:23	Off	√	√			ABS Off 2WD Test 56 West of centre line
57	24-Feb.	1/4 in. Loose Snow On	¼-Ton 4x4 15:01	On	√	√			ABS On 2WD Test 57 West of centre line
58	24-Feb.	1/4 in. Loose Snow On	¼-Ton 4x4 15:09	On	√	√			ABS On 4WD Test 58 West of centre line
59	24-Feb.	1/4 in. Loose Snow On	¾-Ton 4x4 15:16	Off	√	√			ABS Off 2WD Test 59 West of centre line
60	24-Feb.	1/4 in. Loose Snow On	¾-Ton 4x4 15:21	Off	√	√			ABS Off 4WD Test 60 West of centre line
61	24-Feb.	1/4 in. Loose Snow On	1 Ton 4x4 15:38	On	√	√			ABS On 2WD Test 61 East of centre line
62	24-Feb.	1/4 in. Loose Snow On	1-Ton 4x4 15:47	Off	√	√			ABS Off 2WD Test 62 East of centre
63	24-Feb.	1/4 in. Loose Snow On	FWD Car 16:03	On	√	√			ABS On Test 63 West of centre line
64	24-Feb.	1/4 in. Loose Snow On	½-Ton 2x4 16:05 Staff 21	Off	√				ABS Off Test 64 1st 5 east 2nd 5 west
65	24-Feb.	1/4 in. Loose Snow On	FWD Car 16:13	Off	√	√			ABS Off Test 65 West of centre line
66	24-Feb.	3/8 in. Loose Snow On	RWD Car 16:51	On	√	√			ABS On Test 66 East of centre line
67	24-Feb.	3/8 in. Loose Snow On	RWD Car 17:02	Off	√	√			ABS Off Test 67 East of centre line
68	24-Feb.	3/8 in. Loose Snow On	Blazer 17:13	On	√	√			ABS On 2WD Test 68 1st 5 east 2nd 5 west
69	24-Feb.	3/8 in. Loose Snow On	Blazer 17:18	Off	√	√			ABS Off 4WD Test 69 1st 5 east 2nd 5 west

Table 3.6: Test Matrix: February 25 Tests

Test No.	Date	Surface	Vehicle / Time	ABS	Decelerometers Used				Commments
				On/Off	Mk 2	Mk 3	Bomonk	Tapley	
70	25-Feb.	1/8 in. Loose Snow on Pavement - Plowed Not Swept	Blazer 8:49	On	√	√			ABS On 2WD Test 70 East of centre line
71	25-Feb.	1/8 in. Loose Snow on Pavement - Plowed Not Swept	Blazer 8:57	Off	√	√			ABS Off 2WD Test 71 East of centre line
72	25-Feb.	1/8 in. Loose Snow on Pavement - Plowed Not Swept	½-Ton 4x4 9:11	On	√	√			ABS On 2WD Test 72 West of centre line
73	25-Feb.	1/8 in. Loose Snow on Pavement - Plowed Not Swept	½-Ton 4x4 9:19	On	√	√			ABS On 2WD Test 73 West of centre line
74	25-Feb.	1/8 in. Loose Snow on Pavement - Plowed Not Swept	½-Ton 4x4 9:27	Off	√	√			ABS Off 2WD Test 74 West of centre line
75	25-Feb.	1/8 in. Loose Snow on Pavement - Plowed Not Swept	¾-Ton 4x4 9:43	On	√	√			ABS On 2WD Test 75 East of centre line
76	25-Feb.	1/8 in. Loose Snow on Pavement - Plowed Not Swept	¾-Ton 4x4 9:53	Off	√	√			ABS Off 2WD Test 76 East of centre line
77	25-Feb.	1/8 in. Loose Snow on Pavement - Plowed Not Swept	Blazer 10:32	Off	√	√	√	√	ABS Off 2 WD Test 77 West of centre line
78	25-Feb.	1/8 in. Loose Snow on Pavement - Plowed Not Swept	Blazer 10:45	On	√	√	√	√	ABS On 2 WD Test 78 West of centre line
78A	25-Feb.	1/8 in. Loose Snow on Pavement - Plowed Not Swept	1-Ton 4x4 11:10	On	√	√	√	√	ABS On 2WD Test 78A East of centre line
79	25-Feb.	1/8 in. Loose Snow on Pavement - Plowed Not Swept	1-Ton 4x4 11:25	Off	√	√	√		ABS Off 2WD Test 79 East of centre line
80	25-Feb.	1/8 in. Loose Snow on Pavement - Plowed Not Swept	½- on 2x4 11:36	On	√		√		ABS On Staff 21 Test 80 west of centre line
81	25-Feb.	1/8 in. Loose Snow on Pavement - Plowed Not Swept	½-Ton 2x4 11:45	Off	√		√		ABS Off Staff 21 Test 81 West of centre
82	25-Feb.	1/8 in. Partly Compacted Snow on Pavement - note 1	Blazer 13:25	Off	√	√	√	√	ABS Off 2WD Test 82 West of centre line
83	25-Feb.	1/8 in. Partly Compacted Snow on Pavement - note 1	Blazer 13:37	On	√	√	√	√	ABS On 2WD Test 83 West of centre line
84	25-Feb.	1/8 in. Partly Compacted Snow on Pavement - note 1	½-Ton 4x4 13:59	On	√	√	√	√	ABS On 2WD Test 84 East of centre line
85	25-Feb.	1/8 in. Partly Compacted Snow on Pavement - note 1	½-Ton 4x4 14:09	Off	√	√	√	√	ABS Off 2WD Test 85 East of centre line
86	25-Feb.	1/8 in. Partly Compacted Snow on Pavement - note 1	¾-Ton 4x4 14:28	Off	√	√	√	√	ABS Off 2WD Test 86 West of centre line
86A	25-Feb.	1/8 in. Partly Compacted Snow on Pavement - note 1	¾-Ton 4x4 14:38	On	√	√	√	√	ABS On 2WD Test 86A West of centre line
87	25-Feb.	1/8 in. Partly Compacted Snow on Pavement - note 1	FWD Car 14:52	On	√	√	√	√	ABS On Test 87 East of centre Wind scoured
88	25-Feb.	1/8 in. Partly Compacted Snow on Pavement - note 1	FWD Car 15:01	Off	√	√	√	√	ABS Off Test 88 East of centre
89	25-Feb.	1/8 in. Partly Compacted Snow on Pavement - note 1	RWD Car 15:43	Off	√	√	√	√	ABS Off Test 89 West of centre
90	25-Feb.	1/8 in. Partly Compacted Snow on Pavement - note 1	RWD Car 15:53	On	√	√	√	√	ABS On Test 90 West side of centre
91	25-Feb.	1/8 in. Partly Compacted Snow on Pavement - note 1	1-Ton 4x4 16:09	On	√	√			ABS On 2WD Test 91 East of centre line
92	25-Feb.	1/8 in. Partly Compacted Snow on Pavement - note 1	1-Ton 4x4 16:17	Off	√	√			ABS Off Test 92 East of centre
93	25-Feb.	1/8 in. Partly Compacted Snow on Pavement - note 1	Blazer 16:29	Off	√	√	√		ABS Off 2WD Test 93 East of centre.
									Surface snow/sand wind scoured
94	25-Feb.	1/8 in. Partly Compacted Snow on Pavement - note 1	Blazer 16:36	Off	√	√	√		ABS Off 2WD Test 94 West of centre.
									Surface snow/sand wind scoured

Notes:

1. This surface was 1/8 in. snow that had been partly compacted by traffic on pavement. It had been plowed but not swept, and sanded twice

Table 3.7: Test Matrix: February 26 Tests

Date	Surface	Vehicle / Time	ABS	Decelerometers Used				Commments
			On/Off	Mk 2	Mk 3	Bowmonk	Tapley	
26-Feb.	Ice Lane A B C	Blazer 10:09	Off	√	√	√	√	ABS Off 4WD Test 10
								Stop 1-5 Lane A, 6-10 Lane B, 11-15 Lane C
26-Feb.	Ice Lane A	FWD Car 10:38	On	√	√			ABS On Test 11 Lane A
26-Feb.	Ice Lane A	FWD Car 10:48	Off	√	√			ABS Off Test 12 Lane A
26-Feb.	Ice Lane C	RWD Car 11:05	Off	√	√			ABS Off Test 13 Lane C
26-Feb.	Ice Lane C	RWD Car 11:16	On	√	√			ABS On Test 14 Lane C Questionable ABS
26-Feb.	Ice Lane B	½-Ton 4x4 11:34 Windsor OPS	Off		√			ABS Off Test 15 YQB Lane B Decel #180
26-Feb.	Ice Lane B	1-Ton 4x4 12:06	On	√	√			ABS On Test 16 Lane B
26-Feb.	Ice Lane B	1-Ton 4x4 12:14	Off	√	√			ABS Off Test 17 2 WD Lane B
26-Feb.	Ice Lane B	½-Ton 4x4 14:32 Windsor OPS	On		√			ABS On Test 18 2WD YQG Lane B
26-Feb.	Ice Lane A B C	Blazer 14:40	Off	√	√			ABS Off Test 19 4WD
								Stop 1-5 Lane A 6-10 Lane B 11-15 Lane C
26-Feb.	1/4 in. Loose Snow On Compact	Blazer 14:55	Off	√	√	√	√	ABS Off Test 20 4 WD
								Stop 1-5 Lane D 6-10 Lane E 11-15 Lane F
26-Feb.	1/4 in. Loose Snow On Compact	Blazer 15:13	Off	√	√			ABS Off Lane D Test 21
26-Feb.	1/4 in. Loose Snow On Compact	Blazer 15:20	On	√	√			ABS On Lane D Test 22
26-Feb.	1/4 in. Loose Snow On Compact	½-Ton 4x4 15:35	On	√	√	√	√	ABS On 2WD Test 23 Lane E
								Rutting on Packed/Compact Snow Lane E
26-Feb.	1/4 in. Loose Snow On Compact	½-Ton 4x4 15:45	Off	√	√	√	√	ABS Off Test 24 2WD Lane E
								Rutting on Compact/Packed Snow Lane E
26-Feb.	1/4 in. Loose Snow On Compact	¾-Ton 4x4 16:25	Off	√	√			ABS Off Test 25 2WD Lane F
								Firm Compact Snow Base Lane F
26-Feb.	1/4 in. Loose Snow On Compact	¾-Ton 4x4 16:12	On	√	√			ABS On Test 26 2WD Lane F
								Firm Compact Snow Base Lane F
26-Feb.	1/4 in. Loose Snow On Compact	½-Ton 4x4 16:22 Windsor OPS	On		√			ABS On Test 26A 2WD Lane F YQG
26-Feb.	1/4 in. Loose Snow On Compact	½-Ton 4x4 16:27 Windsor OPS	Off		√			ABS Off Test 27 2WD Lane F YQG
26-Feb.	1/4 in. Loose Snow On Compact	FWD Car 17:03	On	√	√	√	√	ABS On Test 28 Lane D E F
								Stop 1-5 Lane D 6-10 Lane E 11-15 Lane F
26-Feb.	1/4 in. Loose Snow On Compact	FWD Car 17:11	Off	√	√	√	√	ABS Off Test 29 Lane D E F
								Stop 1-5 Lane D 6-10 Lane E 11-15 Lane F
26-Feb.	1/4 in. Loose Snow On Compact	RWD Car 17:23	On	√	√			ABS On Test 30 Lane D E F
								Stop 1-5 Lane D 6-10 Lane E 11-15 Lane F
26-Feb.	1/4 in. Loose Snow On Compact	RWD Car 17:31	Off	√	√			ABS Off Test 31 Lane D E F
								Stop 1-5 Lane D 6-10 Lane E 11-15 Lane F
26-Feb.	1/4 in. Loose Snow On Compact	Blazer 17:43	Off	√	√			ABS Off Test 32 4WD Lane D E F
								Stop 1-5 Lane D 6-10 Lane E 11-15 Lane F

Table 3.8: Test Matrix: February 27 Tests

Test No.	Date	Surface	Vehicle / Time	ABS	Decelerometers Used				Commments
				On/Off	Mk 2	Mk 3	Bowmonk	Tapley	
40	27-Feb.	1/4 in. Loose Snow On	Blazer 09:47	Off	√	√			ABS Off Test 40 4WD
41	27-Feb.	1/4 in. Loose Snow On	Blazer 9:55	On	√	√			ABS On Test 41 2WD
42	27-Feb.	1/4 in. Loose Snow On Compact	Blazer 10:01	Off	√	√			ABS Off 4WD Lane F Test 42
									Firm Compact Snow Base Lane F Only
43	27-Feb.	1/4 in. Loose Snow On Compact	Blazer 10:08	On	√	√			ABS On 2WD Lane F Test 43
44	27-Feb.	1/4 in. Loose Snow On	½-Ton 4x4 10:40	On	√	√			ABS On Test 44 2WD
45	27-Feb.	1/4 in. Loose Snow On	½-Ton 4x4 10:43	Off	√	√			ABS Off Test 45 4WD
46	27-Feb.	1/4 in. Loose Snow On Compact	½-Ton 4x4 10:50	Off	√	√			ABS Off 4WD Lane F Test 46
46A	27-Feb.	1/4 in. Loose Snow On Compact	½-Ton 4x4 10:57	On	√	√			ABS On 2WD Lane F Test 46A
47	27-Feb.	1/4 in. Loose Snow On	¾-Ton 4x4 11:18	On	√	√			ABS On Test 47 2WD
47A	27-Feb.	1/4 in. Loose Snow On	¾-Ton 4x4 11:22	Off	√	√			ABS Off Test 47A 2WD
48	27-Feb.	1/4 in. Loose Snow On Compact	¾-Ton 4x4 11:30	Off	√	√			ABS Off 2WD Test 48 Lane F
									Glazing Evident on Lane F
49	27-Feb.	1/4 in. Loose Snow On Compact	¾-Ton 4x4 11:41	On	√	√			ABS On Test 49 2WD Lane F
									Glazing Evident on Lane F

3.3 Results: Measured Friction Coefficients

It should be noted that at least 15 individual decelerometer readings were made for each test case. These values were then averaged. All data plotted and analyzed in subsequent sections is based on the averages that were computed from the individual decelerometer readings.

3.3.1 Effect of ABS On v. Off: Results by Decelerometer and Vehicle Type

The effect of decelerometer type is shown in Figures 3.17 to 3.22 while the effect of vehicle type is plotted in Figures 3.23 to 3.26.

Summary results are presented in Table 3.9. The results varied with respect to decelerometer type, vehicle type, and CRFI level. As a result, overall trends cannot be defined.

The observed variations in friction coefficient are evaluated with respect to their effect on inferred landing distances in Section 3.4.

Table 3.9: Effect of ABS On v. Off

	ERD Mk III	ERD Mk II	Tapley	Bowmonk
Blazer	- at low CRFIs (of ~ 0.1), similar values were with ABS on or off - at CRFIs above 0.2, the values obtained with the ABS off were about 0.05 higher. The max. variation was ~ 0.06.	- at low CRFIs (of about 0.1), the values were similar with ABS on or off - at CRFIs above 0.2, the values obtained with the ABS off were about 0.05 higher. The max. variation was ~ 0.06.	The CRFIs were similar with ABS on or off for CRFIs between 0.3 and 0.5. The max. variation was ~ 0.03.	- Peak Mode: similar results with ABS on or off. The max. variation was ~ .02. - Average Mode: much higher CRFI with ABS off. The max. variation was ~ 0.08.
½-Ton Truck	- at low CRFIs (of ~ 0.1), higher values were with ABS off of ~ 0.02. - at CRFIs above 0.2 - scattered results - CRFIs were generally lower with ABS off. The max. variation was ~ 0.12.	- at low CRFIs (of about 0.1), the values were similar with ABS on or off - at CRFIs above 0.2 - scattered results - CRFIs were generally lower with the ABS off. The max. variation was ~ 0.12.	The CRFIs were similar with ABS on or off for CRFIs between ~ 0.1 and 0.45. The max. variation was ~ 0.02.	- Peak Mode: scattered results with ABS on or off. The max. variation was ~.08. - Average Mode: higher friction with ABS off. The max. variation was ~0.05.
¾-Ton Truck	- at low CRFIs (of about 0.1) – similar values with ABS on or off - at CRFIs above 0.2, the CRFIs were lower with the ABS off. The max. variation was ~ 0.1.	- at low CRFIs (of about 0.1), the values were similar with ABS on or off - at CRFIs above 0.2, the CRFIs were lower with the ABS off. The max. variation was ~ 0.1.	Only tested at high CRFIs - similar CRFIs were similar with ABS on or off. The max. variation was ~ 0.02.	- Peak Mode: lower results with ABS off. The max. variation was ~ .04. - Average Mode: not tested
1-Ton Truck	- at low CRFIs (of about 0.1) - similar values with ABS on or off - at CRFIs above 0.2, the CRFIs were higher with the ABS off. The max. variation was ~ 0.03.	- at low CRFIs (of about 0.1), the values were similar with ABS on or off - at CRFIs above 0.2, the CRFIs were higher with the ABS off. The max. variation was ~ 0.03.	Not tested	- Peak Mode: not tested - Average Mode: similar friction with ABS on or off. The max. variation was ~ 0.01.
RWD Car	- at low CRFIs (of about 0.1) - similar values with ABS on or off - at higher CRFIs - higher with ABS off. The max. variation was ~ 0.06.	- full range of CRFIs - the values were similar with ABS on or off. The max. variation was ~ 0.04	Only tested at high CRFIs – higher CRFIs with ABS off. The max. variation was ~ 0.05.	- Peak Mode: higher CRFIs with ABS off. The max. variation was ~ .04. - Average Mode: not tested
FWD Car	- at CRFIs of about 0.1 - lower values with ABS off – max variation of ~ .05 - at higher CRFIs – similar values with ABS on or off.	- full range of CRFIs - the values were similar with ABS on or off. The max. variation was ~ 0.03	Only tested at high CRFIs – lower CRFIs with ABS off. The max. variation was ~ 0.03.	- Peak Mode: higher CRFIs with ABS off. The max. variation was ~ .08. - Average Mode: not tested

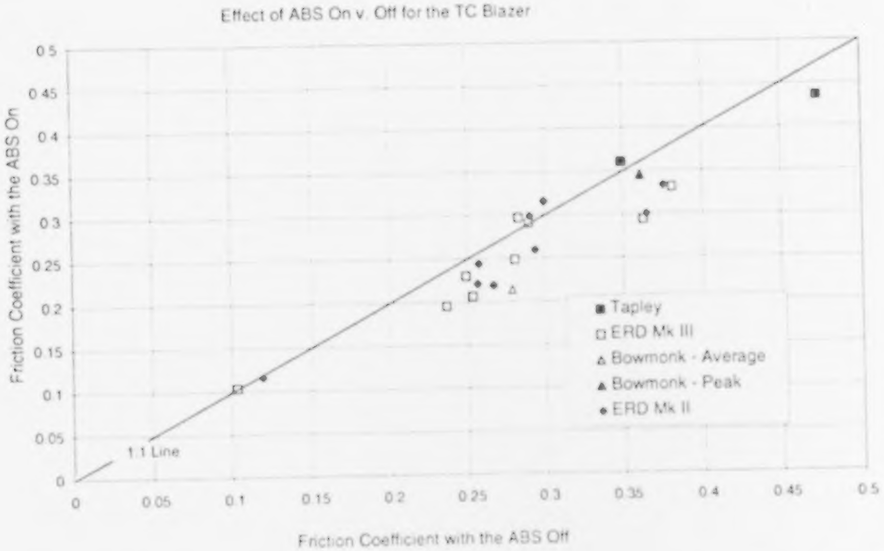


Figure 3.17: Decelerometer Comparison for the Blazer: All Test Surfaces

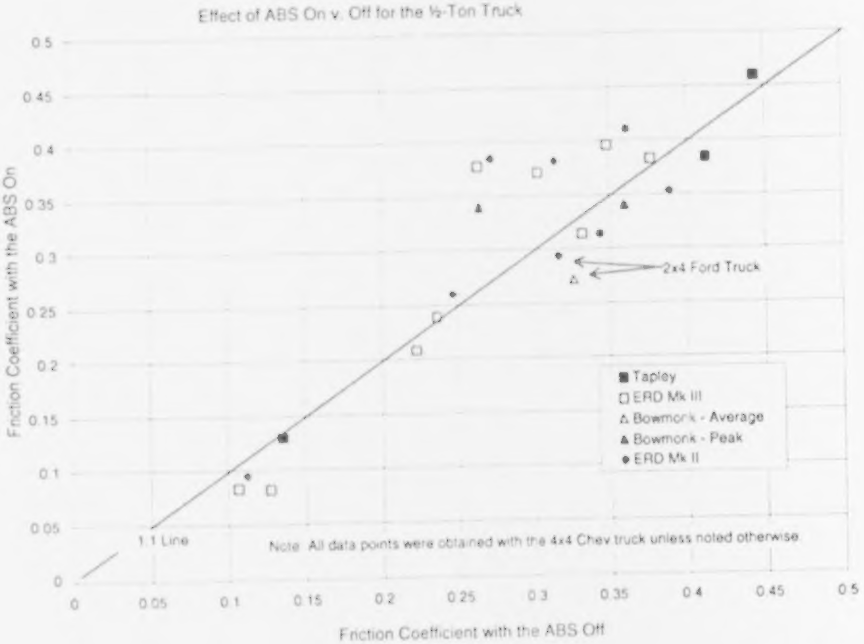


Figure 3.18: Decelerometer Comparison for the ½-Ton Truck: All Test Surfaces

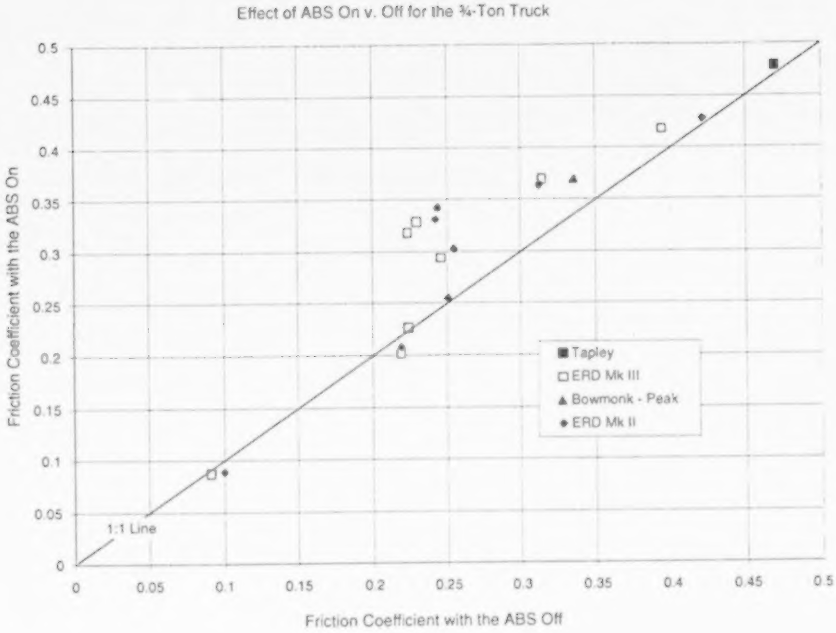


Figure 3.19: Decelerometer Comparison for the ¾-Ton Truck: All Test Surfaces

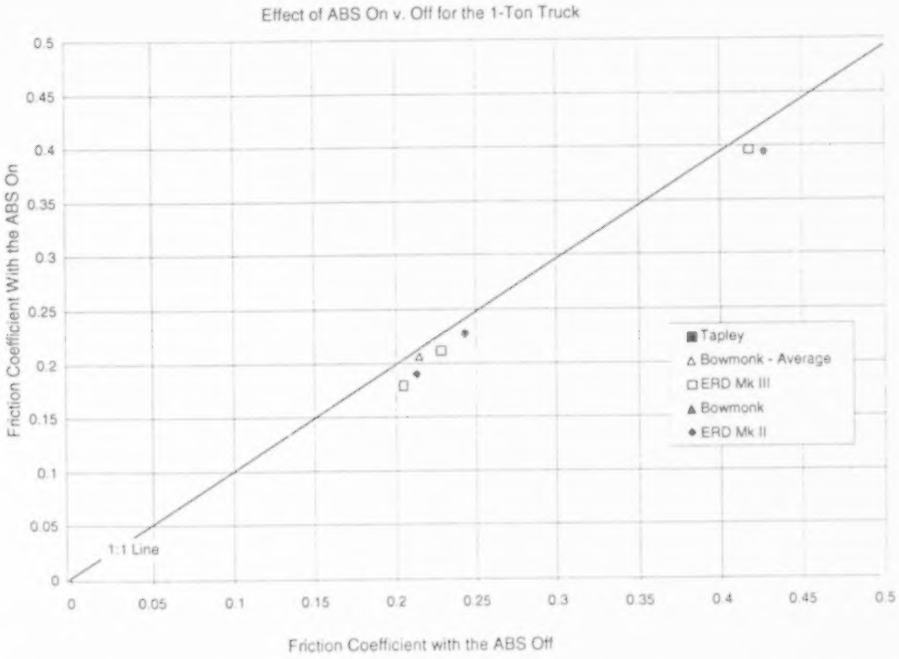


Figure 3.20: Decelerometer Comparison for the 1-Ton Truck: All Test Surfaces

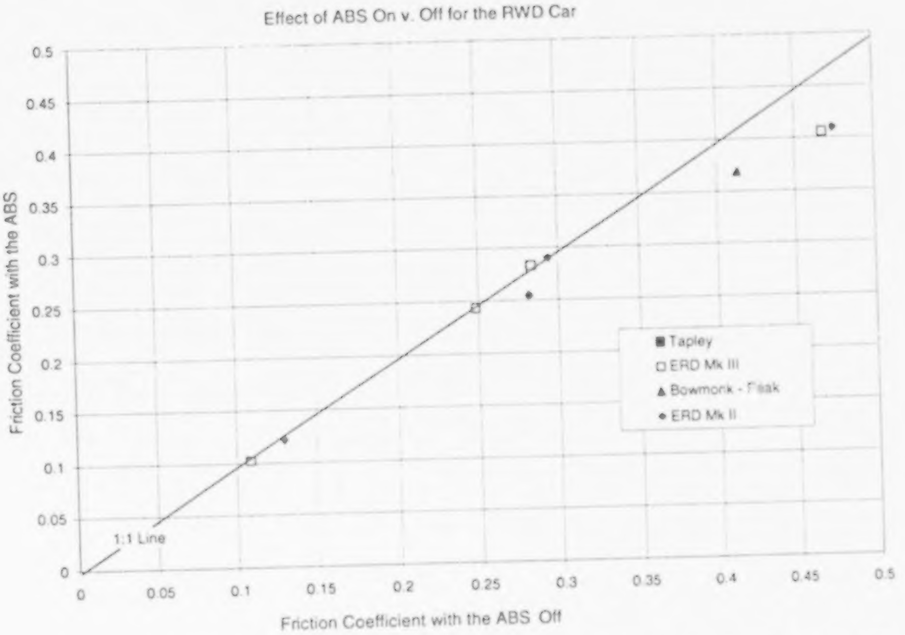


Figure 3.21: Decelerometer Comparison for the RWD Car: All Test Surfaces Combined

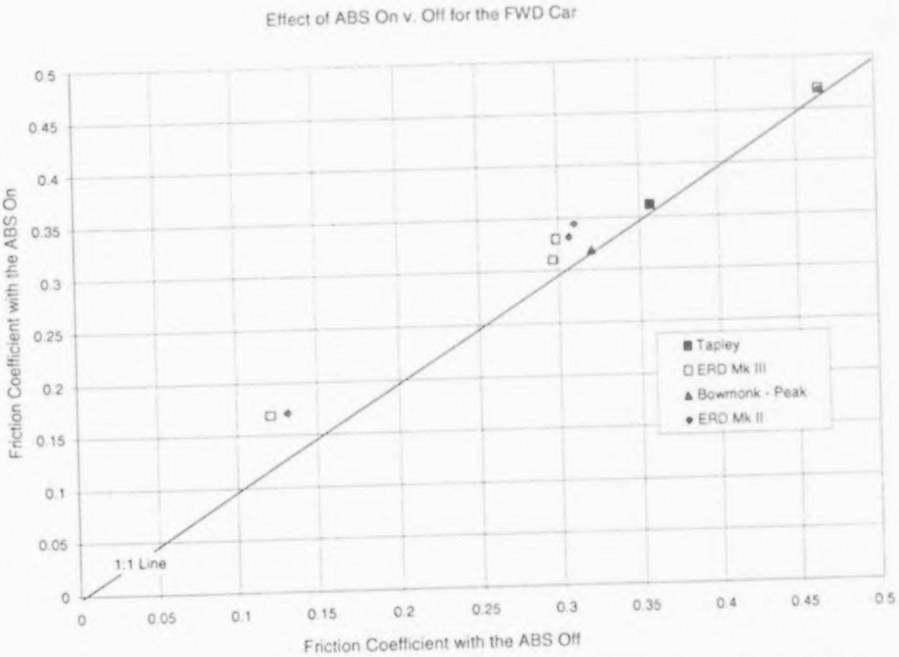


Figure 3.22: Decelerometer Comparison for the FWD Car: All Test Surfaces Combined

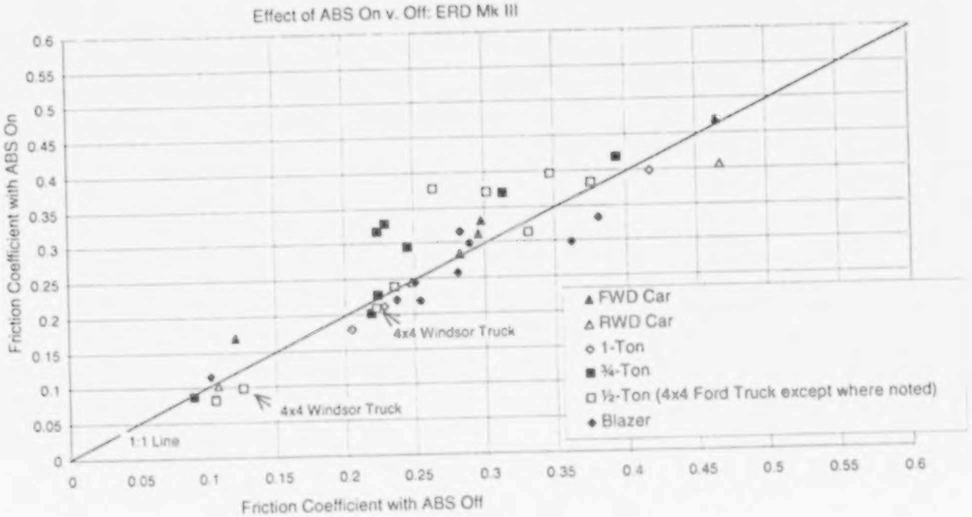


Figure 3.23: Effect of Vehicle for the ERD Mk III: All Test Surfaces Combined

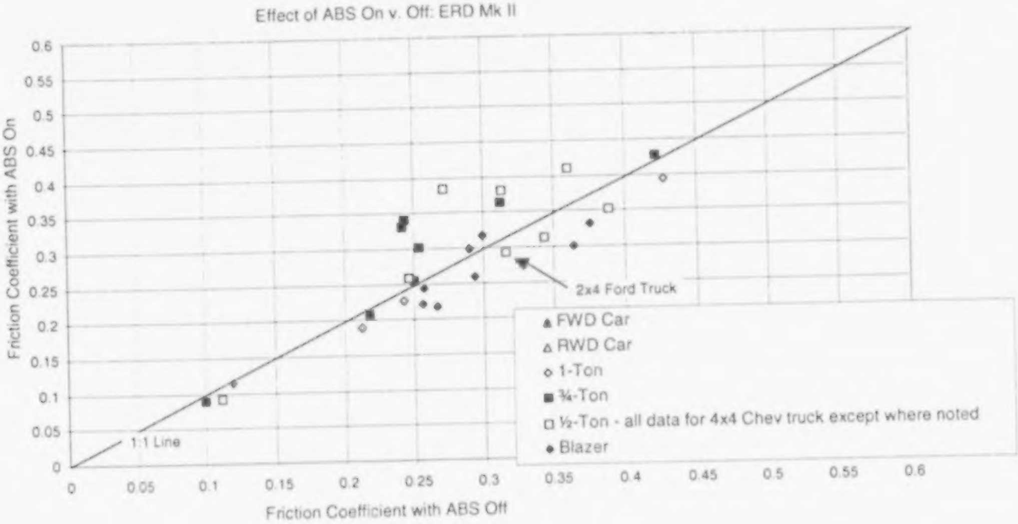


Figure 3.24: Effect of Vehicle for the ERD Mk II: All Test Surfaces Combined

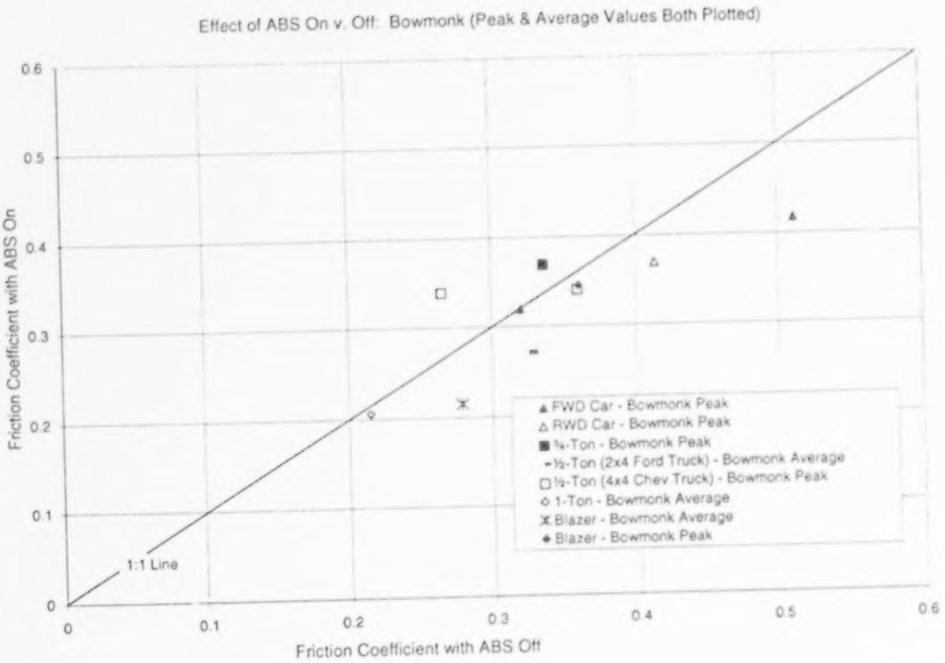


Figure 3.25: Effect of Vehicle for the Bowmonk: All Test Surfaces Combined

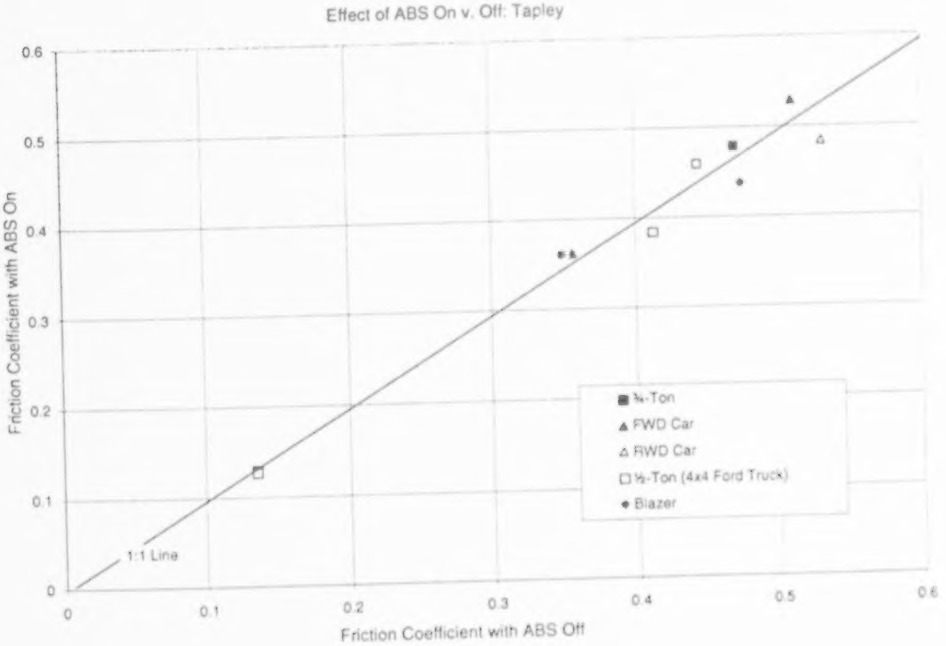


Figure 3.26: Effect of Vehicle for the Tapley: All Test Surfaces Combined

3.3.2 Effect of Decelerometer Type

The effect of decelerometer type is shown in Figures 3.27 to 3.30.

Summary results are presented in Table 3.10, using the ERD Mk III as the basis of comparison. The following general observations can be made:

(a) ERD Mk II v. ERD Mk III: The ERD Mk III consistently read lower by about 0.01 on average than did the ERD Mk II over the full range of friction coefficients.

(b) Tapley v. ERD Mk III: The ERD Mk III consistently read about 0.05 lower than did the Tapley over the full range of friction coefficients.

(c) Bowmonk v. ERD Mk III:

  a. Peak values read by the Bowmonk – The results are scattered as Bowmonk peaks were both above and below the readings from the ERD Mk III. The maximum variation between the Bowmonk peak and the ERD Mk III was about 0.1.

  b. Average values read by the Bowmonk – Only limited comparisons can be made, as only two data points are available. However, these data indicate that the Bowmonk average and the ERD Mk III friction coefficients are similar.

Table 3.10: Effect of Decelerometer Type

	ERD Mk II v. ERD Mk III	Tapley v. ERD Mk III	Bowmonk (Peak) v. ERD Mk III	Bowmonk (Peak) v. ERD Mk III
Blazer	Lower CRFIs with the ERD Mk III for all friction levels	Lower CRFIs with the ERD Mk III for all friction levels – max. variation of about 0.08	Lower CRFIs with the ERD Mk III for all friction levels – max. variation of about 0.05	Only one data point – similar CRFIs
½-Ton	Lower CRFIs with the ERD Mk III for all friction levels	Lower CRFIs with the ERD Mk III for all friction levels – max. variation of about 0.08	Scattered results – no clear trend	No data available
3/4-Ton	Lower CRFIs with the ERD Mk III for all friction levels	CRFI data only available for high CRFIs - Lower CRFIs with the ERD Mk III – max. variation of about 0.08	CRFI data only available for high CRFIs - Higher CRFIs with the ERD Mk III – max. variation of about 0.07	No data available
1-Ton	Lower CRFIs with the ERD Mk III for all friction levels	No data available	No data available	Only one data point – similar CRFIs
Rear Wheel Drive Car	Lower CRFIs with the ERD Mk III for all friction levels	CRFI data only available for high CRFIs - Lower CRFIs with the ERD Mk III – max. variation of about 0.05	Only one data point – Higher CRFI with the ERD Mk III by about 0.05	No data available
Front Wheel Drive Car	Lower CRFIs with the ERD Mk III for all friction levels	CRFI data only available for high CRFIs - Lower CRFIs with the ERD Mk III – max. variation of about 0.05	CRFI data only available for high CRFIs - Lower CRFIs with the ERD Mk III – max. variation of about 0.05	No data available

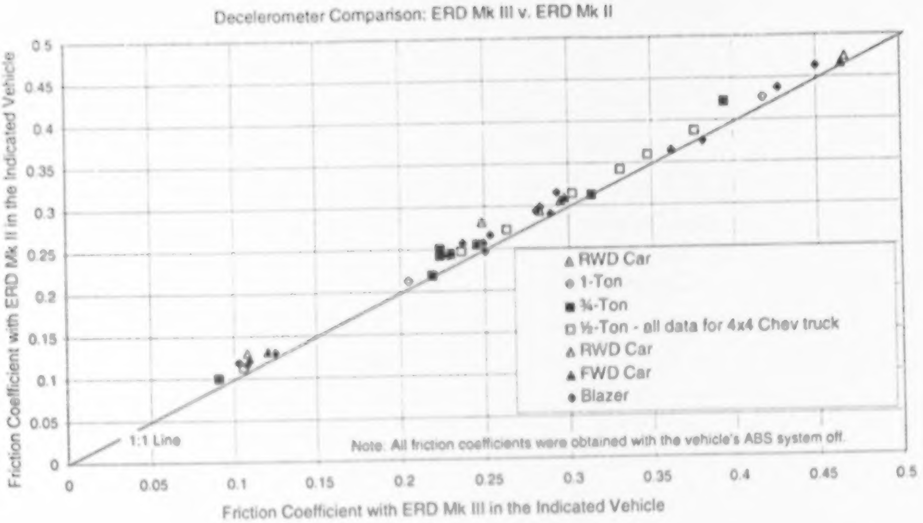


Figure 3.27: Decelerometer Comparison: ERD Mk II v. ERD Mk III

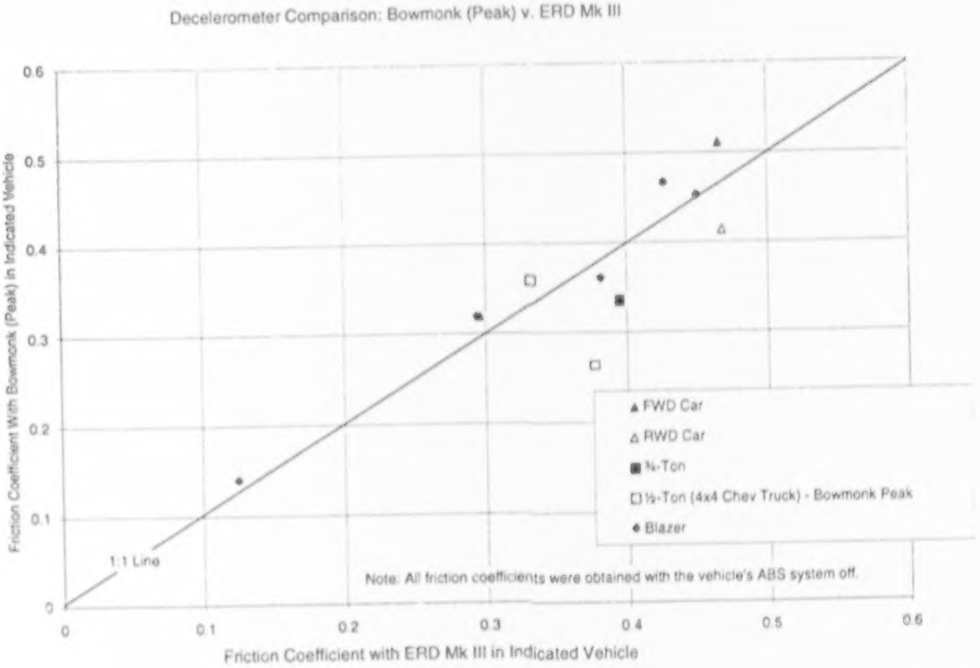


Figure 3.28: Decelerometer Comparison: Bowmonk (Peak) v. ERD Mk III

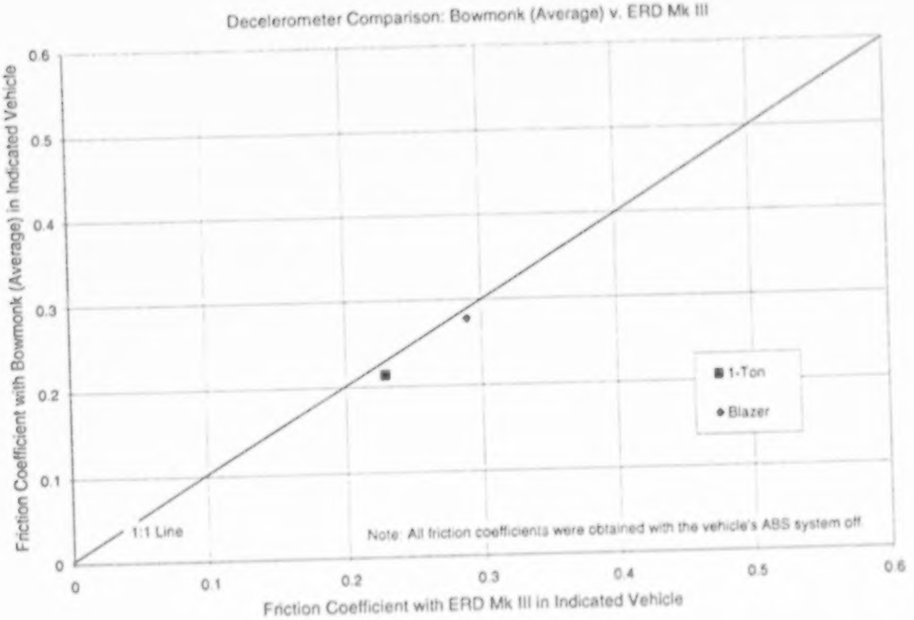


Figure 3.29: Decelerometer Comparison: Bowmonk (Average) v. ERD Mk III

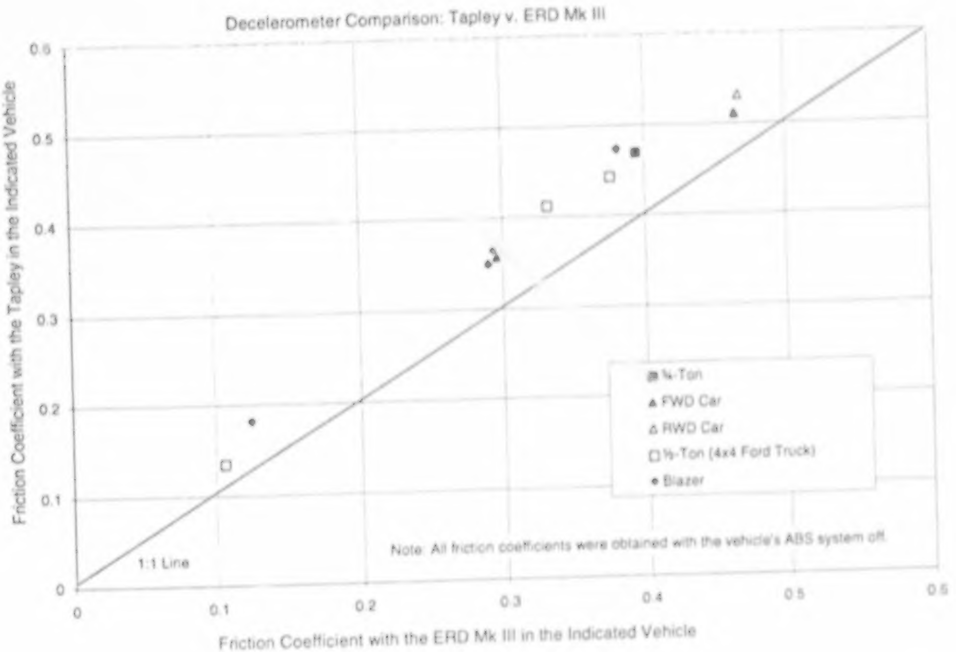


Figure 3.30: Decelerometer Comparison: Tapley v. ERD Mk III

3.4 Effect of ABS ON v. OFF On Inferred Landing Distances

3.4.1 Analysis Purpose and Approach

The measured friction coefficients varied somewhat with all of the parameters investigated. These variations need to be put into perspective to assess their significance. The Landing Distances (LDs) in the AIP [3] were used to assess the significance of the observed variations in friction coefficient as they are related to the CRFI.

This was done as described in Section 2. The analyses were done with respect to an unfactored AIP LD of 914.6 m (3000 ft.), and for no reverse thrust. Landing distances were computed for each friction coefficient using Equation [2.1], in Section 2. Landing distances were only computed for CRFI values in the range of 0.18 to 0.60, as this is the range of CRFIs given in the AIP [3].

The Blazer and the ERD Mk III were used as the bases of comparison, in keeping with the approach used to compare the friction coefficients measured by the various vehicles and decelerometers (Section 3.3).

3.4.2 Effect of Decelerometer Type

The landing distances inferred from the test data are shown in Figures 3.31 to 3.36 for friction coefficients exceeding 0.18.

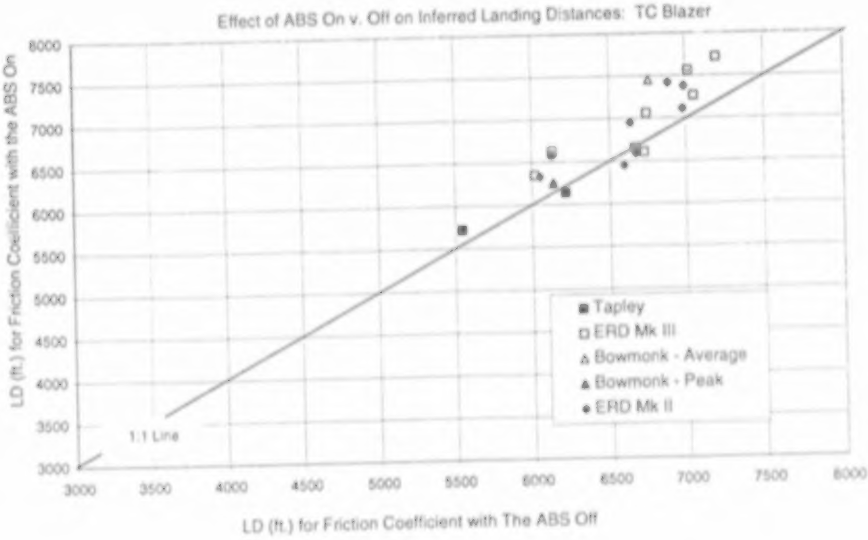


Figure 3.31: Inferred Landing Distances: Decelerometer Comparison for the Blazer for All Test Surfaces Combined

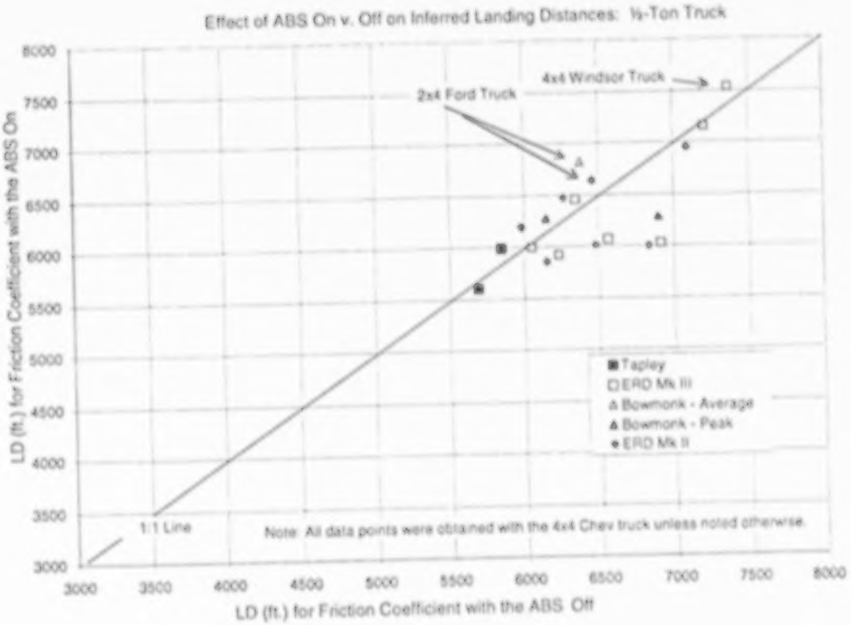


Figure 3.32: Inferred Landing Distances: Decelerometer Comparison for the ½-Ton for All Test Surfaces Combined

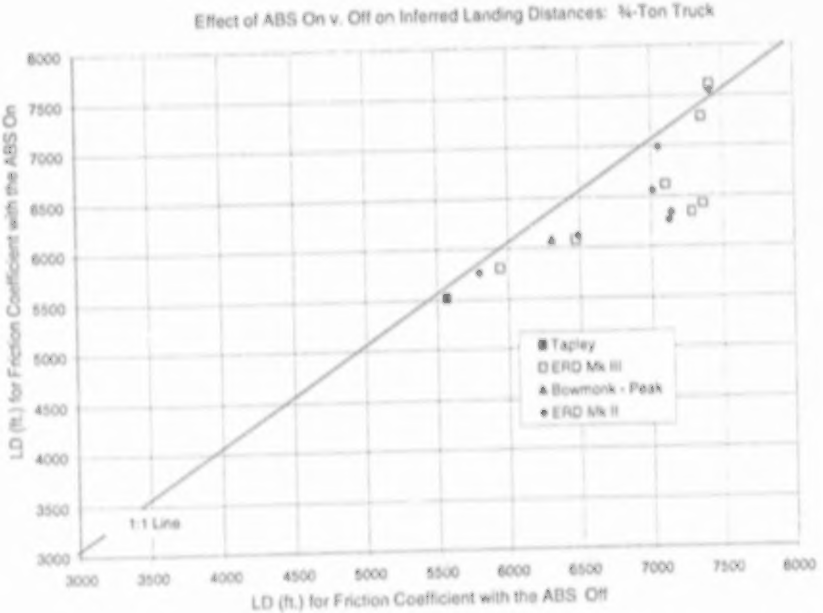


Figure 3.33: Inferred Landing Distances: Decelerometer Comparison for the ¾-Ton for All Test Surfaces Combined

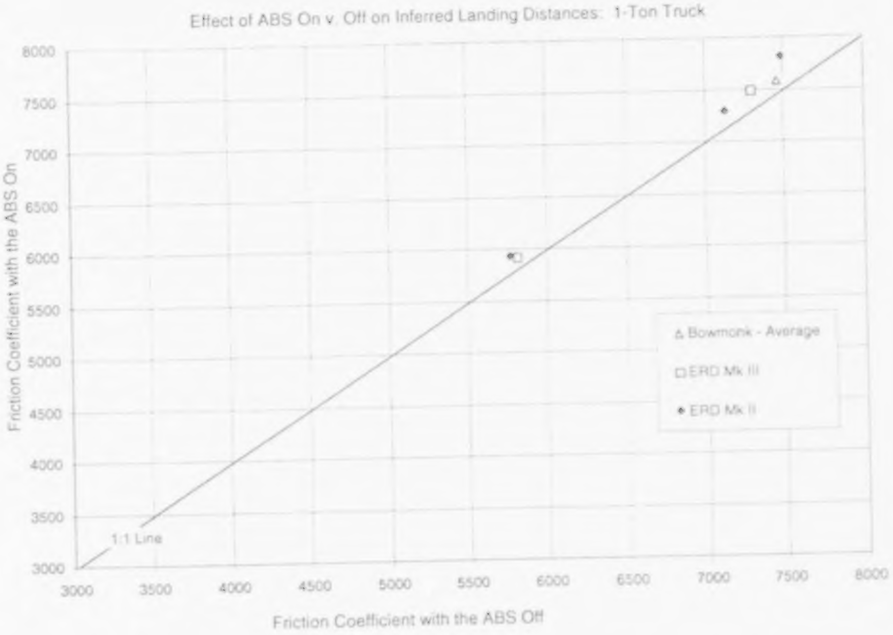


Figure 3.34: Inferred Landing Distances: Decelerometer Comparison for the 1-Ton for All Test Surfaces Combined

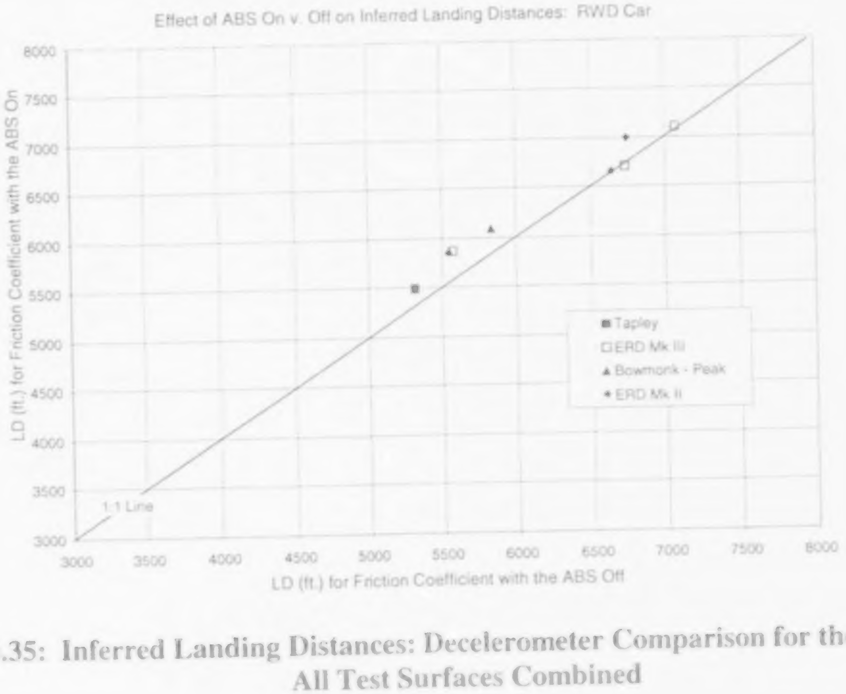


Figure 3.35: Inferred Landing Distances: Decelerometer Comparison for the RWD Car for All Test Surfaces Combined

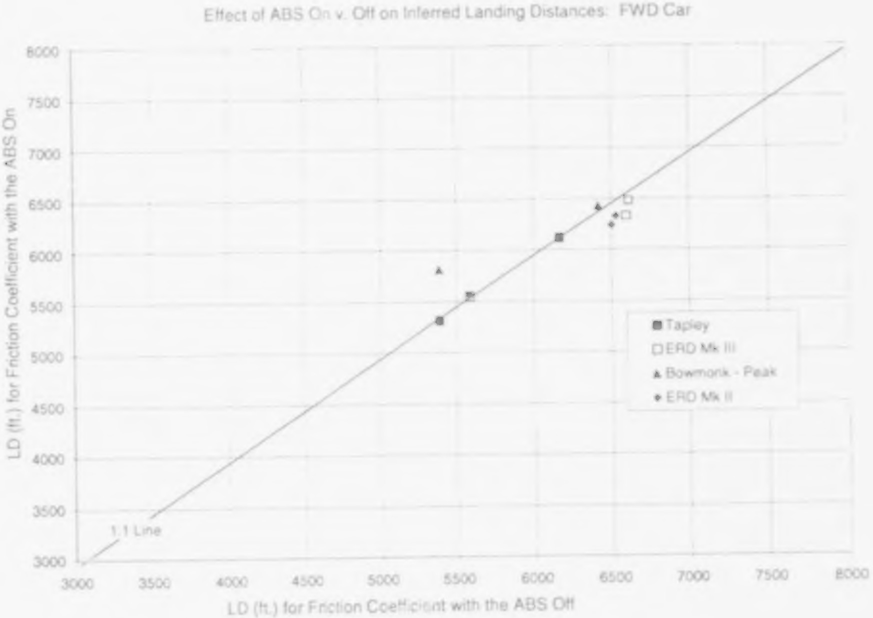


Figure 3.36: Inferred Landing Distances: Decelerometer Comparison for the FWD Car for All Test Surfaces Combined

3.4.3 Effect of Vehicle Type on Inferred Landing Distance

The landing distances inferred from the test data (for friction coefficients exceeding 0.18) are shown in Figures 3.37 to 3.40.

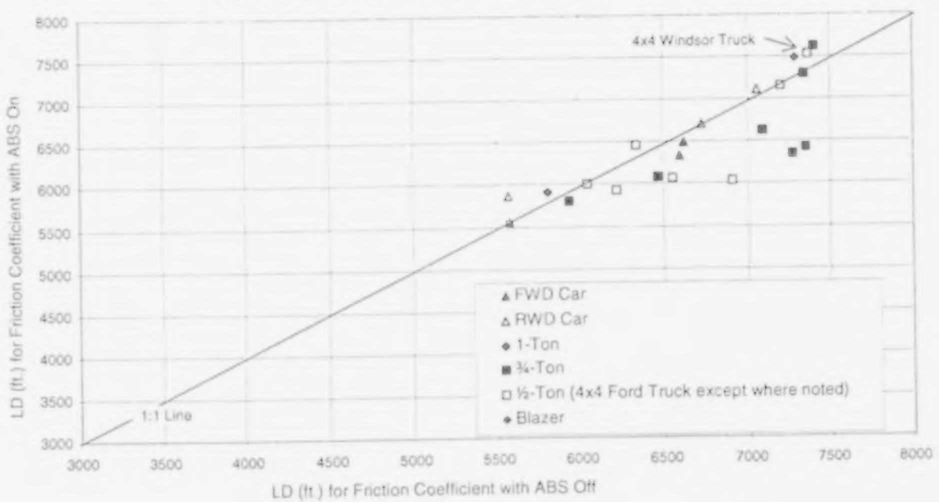


Figure 3.37: Effect on Inferred Landing Distances: Vehicle Comparison for the ERD Mk III for All Test Surfaces Combined

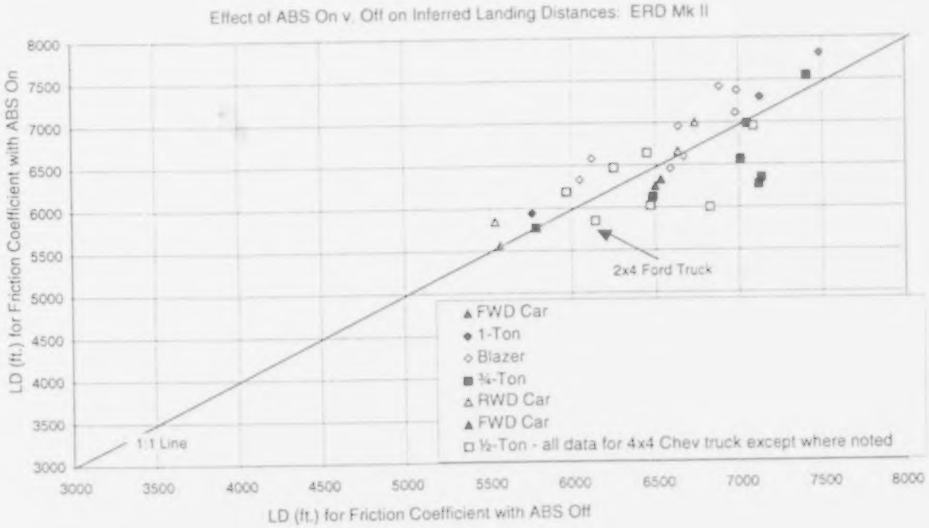


Figure 3.38: Effect on Inferred Landing Distances: Vehicle Comparison for the ERD Mk II for All Test Surfaces Combined

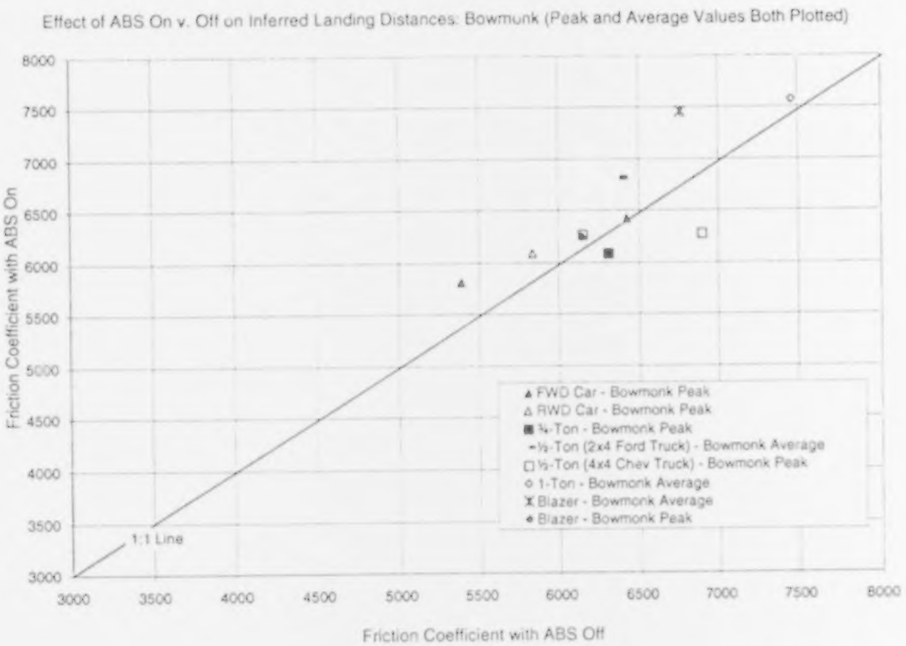


Figure 3.39: Effect on Inferred Landing Distances: Vehicle Comparison for the Bowmonk for All Test Surfaces Combined

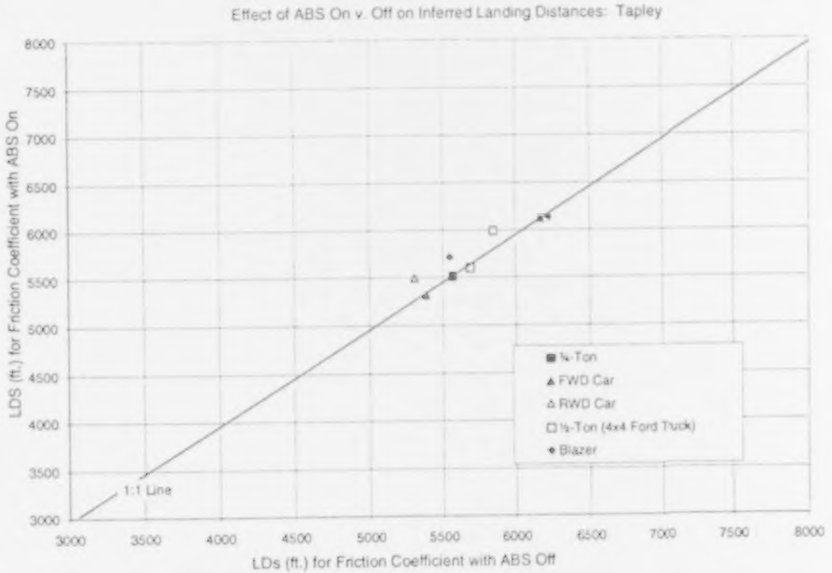


Figure 3.40: Effect on Inferred Landing Distances: Vehicle Comparison for the Tapley for All Test Surfaces Combined

3.5 Discussion and Summary

3.5.1 Effect of ABS On v. Off: Measured Friction Coefficients

The following observations can be made:

- Overall trends cannot be defined although trends were observed for each vehicle. Nevertheless, substantial differences in CRFI were observed in some cases depending upon whether or not the vehicle's ABS was on or off. The effect of ABS on versus off depended on the specific vehicle, decelerometer, and surface (which affected the friction level) under consideration. The effect of ABS on versus off ranged from:
  - increasing the respective friction coefficient to;
  - decreasing the respective friction coefficient to; and
  - no effect.

- The observed friction coefficient variations must be examined with respect to their effect on inferred landing distances to evaluate their significance.

- Comparison to the 2002 test results [1] – the CRFI variations observed this year (by having the ABS on or off) are larger than those obtained during the 2002 program (which were primarily obtained with the Blazer and a ½-ton truck). For reference, results for the ERD Mk III from the 2002 tests are shown in Figure 3.41.

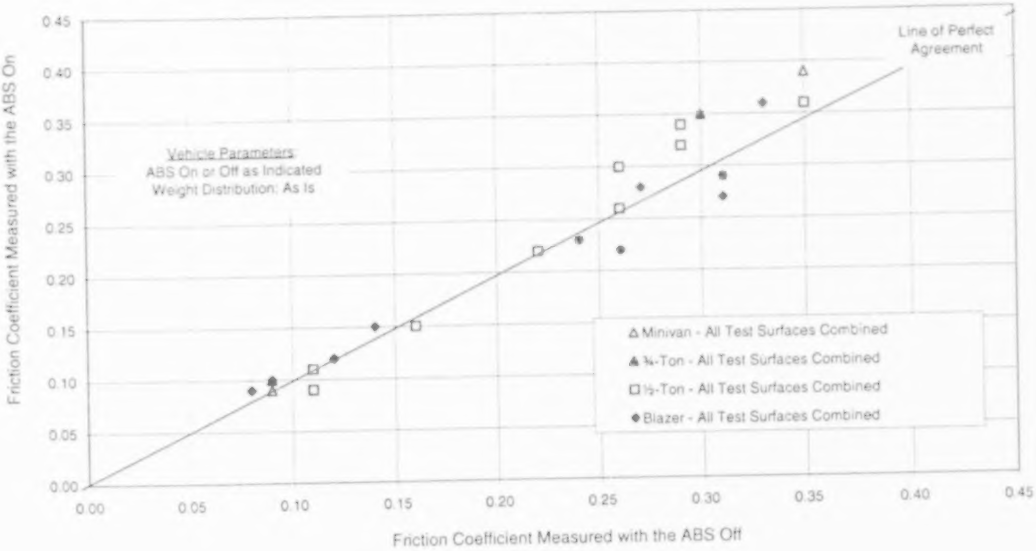


Figure 3.41: Effect of ABS On v. Off: Results from 2002 for the ERD Mk III [1]

3.5.2 Effect of ABS On v. Off: Inferred Landing Distances

The maximum variations in inferred landing distances are summarized in Table 3.11.

The largest variations were observed for the Blazer, the ½-ton, and the ¾-ton on February 24 during tests done with 6 mm (1/4 in.) of loose snow on bare pavement. Data were only obtained with the ERD Mk III and the ERD Mk II on that day. The Tapley and Bowmonk were not tested on that day as they were not available.

Table 3.11: Maximum Variation in Inferred Landing Distances for ABS On v. Off

	ERD MK III	ERD Mk II	Tapley	Bowmonk Peak	Bowmonk Average
Blazer	- 549	- 533	-171	-106	-695
½-Ton	876	829	-152	-448	614
¾-Ton	924	853	41	220	no data
1-Ton	-202	-334	no data	no data	-116
RWD Car	-302	-310	-189	-256	no data
FWD Car	257	258	34	-427	no data

Notes:

1. The above differences in inferred LD are in ft.
2. Negative and positive variations indicate that the inferred LD based on the friction coefficient measured with the ABS off was shorter or longer, respectively.

The above maxima are larger than the maximum variation in inferred landing distance observed during the 2002 tests, which was 449 ft. (Figure 3.42 and Table 3.12). This difference may be due to differences in surface conditions as no tests were done in 2002 on loose snow on pavement.

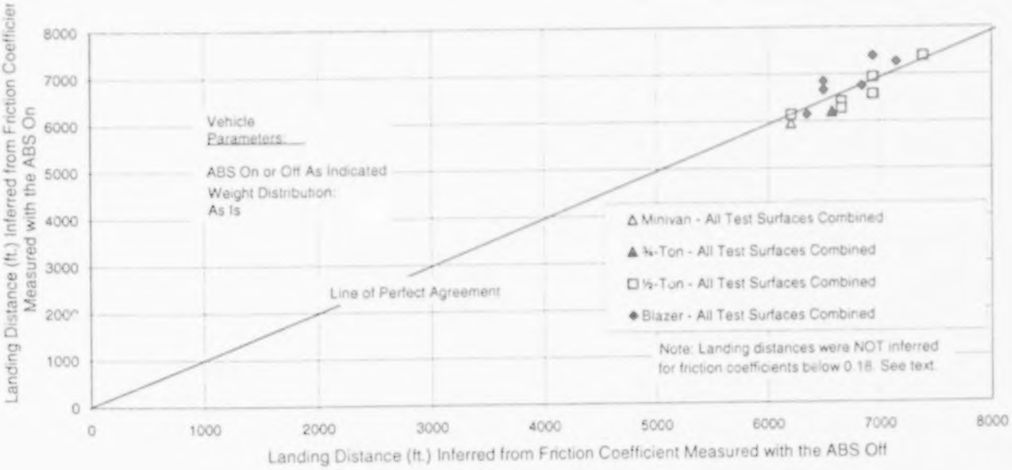


Figure 3.42: Effect on Inferred Landing Distances During the 2002 Tests [1]: ABS On or Off for the ERD Mk III for All Test Surfaces Combined

Table 3.12: Effect of ABS On or Off for the 2002 Tests [1]: Maximum Differences in Inferred Landing Distances

	Max. Variation (ft.) in Inferred Landing Distances (notes 1 and 2) for:			
	Blazer: ABS on v. ABS off	½-Ton: ABS on v. ABS off	¾-Ton: ABS on v. ABS off	Minivan: ABS on v. ABS off
ERD Mk III	449	386	369 (only 1 data pt in range of analyses)	247 (only 1 data pt in range of analyses)
ERD Mk II	424	404	369 (only 1 data pt in range of analyses)	182 (only 1 data pt in range of analyses)
Tapley	230 (only 2 data pts in range of analyses)	51 (only 1 data pt in range of analyses)	not tested	not tested
Bowmonk	212 (only 1 data pt in range of analyses)	57 (only 1 data pt in range of analyses)	not tested	not tested

Notes:
1. The maximum differences are with respect to an unfactored LD in the AIP of 3000 ft. for no reverse thrust.
2. The above values do not apply to friction coefficients less than 0.18.

3.5.3 Decelerometer Comparison

General comparisons are made below with the results from the 2002 program [1]:

- uniformity of results from decelerometers - each decelerometer type produced different results in both programs.

- ERD Mk II v. ERD Mk III – the results obtained this year differ from the 2002 results. In 2002, the two ERDs produced essentially the same value. Some ERD Mk III readings were higher than those for the ERD Mk II while others were lower. In contrast, this year, the ERD Mk III read lower than did the ERD MK II in almost all cases (Figure 3.27) although the variation was relatively small (i.e., about 0.01 on average – equation 3.1). This is discussed further in Section 4.

- Best-fit linear regression:
- ERD Mk III CRFI = 0.9655 * ERD MK II CRFI [3.1]
- Correlation coefficient (r^2): 0.9928

- Tapley v. ERD Mk III – The results from this year are similar to those from last year. In both years, the Tapley read about 0.05 higher than did the ERD Mk III.

(a) Bowmonk v. ERD Mk III – direct comparisons are difficult as the Bowmonk used this year was a newer model, and it was used to record both peaks and averages. Based on the peak values (which represent the majority of the Bowmonk data that were obtained), more variation was observed this year between the Bowmonk and the ERD Mk III readings.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

4.1.1 CRFI Quality Assurance

Field data have been collected at five airports during two visits to each one to compare the CRFIs measured by the site vehicles with those measured by the Transport Canada system (which was comprised of the Blazer, the ERD Mk II, and an operator from North Bay airport). Data were acquired for a range of surfaces at each airport.

Field data have also been obtained to evaluate the effect of different operators.

This data set allows preliminary conclusions, as follows:

- The CRFI variations between the airport systems and the Transport Canada system varied with the airport and Circuit. As expected, more small landing distance variations were observed than large ones. Seventy per cent of the inferred landing distances for these cases varied by less than 500 ft. The maximum variation in inferred landing distance was 826 ft. (Note that all references made to inferred landing distances apply to an unfactored landing distance of 3000 ft., and to no reverse thrust).

- The CRFI variations between the site systems and the Transport Canada systems differed among the airports. They also differed between the two site visits made to each airport. For Circuit 1, the variations were of lesser magnitude and they were both positive and negative. For Circuit 2, the variations were of larger magnitude and almost always positive (which indicates that the CRFIs measured by the Transport Canada system were larger than the site systems). The reason for this difference is unclear.

- Generally, greater variation was observed between the Transport Canada system and the airport systems for sites that used the ERD Mk III as part of their system.

- In all cases, similar results were obtained with the Transport Canada and the site operators. The average CRFI variation was 0.013, with a maximum variation of 0.04. This probably indicates that the operators had all been trained to employ similar measurement techniques. It can be concluded that switching the operators did not affect the CRFI readings significantly, compared to the other differences seen between vehicle-decelerometer pairs.

- Instrumentation problems were encountered with the ERDs used in the Transport Canada system that limits the strength of the conclusions that can be drawn.

4.1.2 Effect of ABS Disabled or Not

Field data have been collected during a one-week test period at North Bay airport to compare the CRFIs measured with a vehicle's ABS system on or off for:

- six generic vehicle types;
- a range of different winter surfaces; and
- three decelerometer types.

This data set has significantly expanded the one that was obtained during a similar test program conducted in 2002 [1]. The following conclusions can be drawn from the whole data set:

- No universal trends were apparent although trends were evident for each vehicle. The effect of ABS on versus off depended on the specific vehicle, decelerometer, and surface (which affected the friction level) under consideration. The effect of ABS on versus off ranged from:
    - ▫ increasing the respective friction coefficient to;
    - ▫ decreasing the respective friction coefficient to; and
    - ▫ no effect

  The above finding is similar to that obtained during the 2002 test data [1], which were primarily obtained with the ERD in the Blazer and a ½-ton truck.

- The observed CRFI variations were examined with respect to their effect on inferred landing distances. (Note that all references made to inferred landing distances apply to an unfactored landing distance of 3000 ft., and to no reverse thrust).

  The maximum variations in inferred landing distances are summarized in Table 4.1. The largest variations were observed for the Blazer, the ½-ton, and the ¾-ton on February 24 during tests done with 6 mm (1/4 in.) of loose snow on bare pavement. Data were only obtained with the ERD Mk III and the ERD Mk II on that day. The Tapley and Bowmonk were not tested on that day as they were not available.

Table 4.1: Maximum Variation in Inferred Landing Distances for ABS On v. Off

	ERD MK III	ERD Mk II	Tapley	Bowmonk Peak	Bowmonk Average
Blazer	- 549	- 533	-171	-106	-695
½-Ton	876	829	-152	-448	614
¾-Ton	924	853	41	220	no data
1-Ton	-202	-334	no data	no data	-116
Rear Wheel Drive Car	-302	-310	-189	-256	no data
Front Wheel Drive Car	257	258	34	-427	no data

Notes:

1. The above differences in inferred LD are in ft.
2. Negative and positive variations indicate that the inferred LD based on the friction coefficient measured with the ABS off was shorter or longer, respectively.

The above maxima are larger than the maximum variation in inferred landing distance observed during the 2002 tests [1], which was 449 ft. This difference may be due to differences in surface conditions as no tests were done in 2002 on loose snow on pavement. The 2002 tests were all done on bare ice and compacted snow.

It appears that the effect on CRFIs produced by ABS on versus off depends upon what the surface that becomes sacrificial. If the base is bare, then, the tires cut through the loose snow cover and the tires become the sacrificial surface. In this case, the CRFIs are more affected by ABS on versus off. On ice and compacted snow, the ice and snow are the sacrificial surface.

4.1.3 Effect of Decelerometer Type

Tests were done with the Electronic Recording Decelerometer (ERD Mk II and ERD Mk III), the Tapley, and the Bowmonk (which was set to record either the peak or the average friction coefficient). The following conclusions can be drawn:

- The decelerometer types produced different values, which is similar to the results obtained during the 2002 test program [1].

- ERD Mk II v. ERD Mk III: Variable results were obtained, as follows:
    - Circuit 1 Tests – no comparisons are possible as the ERD Mk III was later found to be out of calibration (although it had a valid calibration certificate). This is believed to be responsible for the variations that were observed between the ERD Mk II and the ERD Mk III during Circuit 1. The ERD Mk III was recalibrated for the remaining parts of the test program.
    - Circuit 2 Tests – the ERD Mk II and the ERD Mk III read similar values.
    - ABS effect tests (which were conducted subsequently with the same two ERDs) – the relationship varied from the Circuit 2 tests as the ERD Mk III read lower than did the ERD Mk II in almost all cases, although the variation was slight (i.e., about 0.01 on average over the full range of friction coefficients).

  This finding differs from the results of the 2002 test program [1], which showed that the ERD Mk II and the ERD Mk III produced similar values.

- Tapley v. ERD Mk III: The ERD Mk III consistently read about 0.05 lower than did the Tapley over the full range of friction coefficients. This finding is similar to the result from a similar program conducted in 2002 [1].

- Bowmonk v. ERD Mk III: The comparison depended upon whether peak or average Bowmonk values are compared as follows:
    - Peak values read by the Bowmonk – The results are scattered as the Bowmonk peaks were both above and below the readings from the ERD Mk III. The maximum variation in friction coefficient between the Bowmonk peak and the ERD Mk III was about 0.1.

Direct comparisons with the 2002 Program [1] are difficult as the Bowmonk used this year was a newer model that allowed the operator to select whether peaks or averages are to be recorded. However, there was less variability between the peaks measured by the Bowmonk during the 2002 Program [1] and the ERD values. During 2002, the Bowmonk typically read about 0.02 to 0.03 higher than did the ERD.

- Average values read by the Bowmonk – only limited comparisons can be made, as only two data points are available. However, these data indicate that the Bowmonk average and the ERD Mk III friction coefficients are similar.

4.2 Recommendations

4.2.1 CRFI Quality Assurance

The following issues are believed to warrant further investigation:

- More testing is required before firm conclusions can be drawn. However, before more testing is conducted, it is recommended that Transport Canada evaluate the stability of the standard used as the basis of comparison for this project.

- Decelerometer calibration and certification – it is recommended that Transport Canada review current requirements.

- Decelerometer acceptance and regulation – the tests have shown that different values were obtained from different decelerometer types. The significance of these variations should be evaluated by Transport Canada, which does not distinguish between decelerometer types at present for regulations or advisories.

- Further evaluation – a number of issues warrant further investigation as follows:
    - The CRFI variations measured in this project should be compared to the friction coefficient variations observed during other past large-scale calibration projects that have been done for other devices, such as the Griptester.
    - The significance of the observed CRFI variations, and their effect on landing distance variations, should be assessed in context with the other factors that have been taken into account in developing the landing distance tables in the AIP.

4.2.2 Effect of ABS Disabled or Not

The recommended actions depend upon whether or not the observed variations in inferred landing distances are considered to be significant. Transport Canada should make this evaluation.

If the observed variations are considered to be significant, then no changes are recommended to the current Transport Canada practice of disabling the ABS system for CRFI measurement.

If the observed variations are not considered to be significant, then it is recommended that Transport Canada consult other parties (such as the decelerometer manufacturers and the FAA) to develop a consistent position on this issue. This may identify the need for more testing. However, further testing is not recommended at this time.

REFERENCES

[1] Comfort, G., and Ryan, M., 2002, *Effect of Vehicle Parameters on the Friction Coefficients Measured by Decelerometers on Winter Surfaces*, TP 13980E Transportation Development Centre, Transport Canada.

[2] Comfort, G., and Gong, Y., 1998, *Analysis of the Friction Factors Measured by the Ground Vehicles at the 1998 North Bay Trials*, TP 13366E Transportation Development Centre, Transport Canada.

[3] AIP, 2002, *Aeronautical Information Publication*, TP 2300.

APPENDIX A

VEHICLES AND PROCEDURES USED DURING THE CRFI ASSURANCE TESTS

APPENDIX A.1
SITE VEHICLES FOR THE CRFI SYSTEM VERIFICATION STUDY

Transport Canada – 1991 Chevrolet Blazer

Airport 1 – 1992 GMC 1500

[redacted]

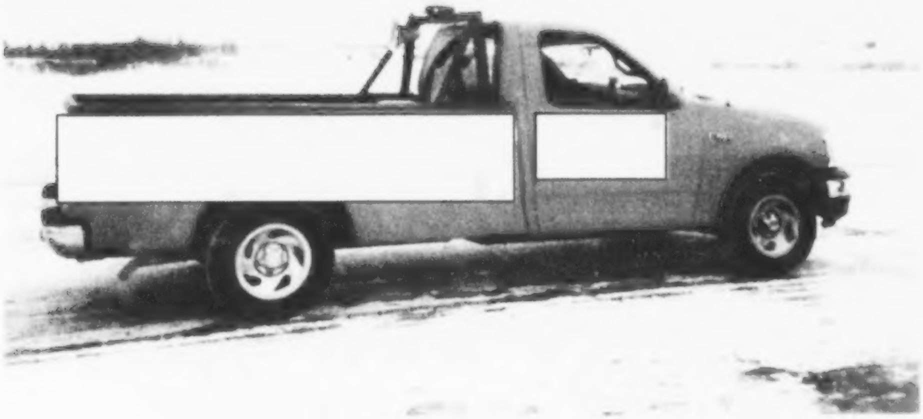
Airport 3 – 1993 GMC 2500SL

[redacted]

Airport 3 – 1997 Chevrolet 2500 Cheyenne

[redacted]

Airport 5 – 2002 Ford F150


[redacted]
[redacted]

Airport 4 – 1989 Chevrolet 1500 Cheyenne:

[redacted]

Airport 2 – 1996 Ford F350

[redacted]

Airport 2 – 2003 Chevrolet 1500 Silverado

[redacted]

APPENDIX A.2

PROCEDURE FOR WEIGHING THE VEHICLES AND MEASURING THEIR TIRE FOOTPRINT AREA

These data were collected at the same time. First the vehicles were lifted, and the tires prepared for imprinting with an art charcoal powder. Load cells were placed under the tires, and zeroed. The vehicle was then lowered, producing tire footprint imprints that were later analyzed. The vehicle weight was recorded when all of the its weight was supported by the four load cells. The field procedure is defined in greater detail below.

a) The vehicle was raised in the garage with the on-site hoist or jack, as available at the sites. It should be noted that the operator was not in the vehicle when it was raised or weighed. This was done for a number of reasons:
   i. safety
   ii. the weight of the operator is a small component of the overall weight (i.e., in the range of 5 percent
   iii. the vehicle may be operated by different operators which makes it difficult to obtain a precise determination for all conditions

b) An area was cleaned on each tire of any loose dirt, gravel, sand, or snow. The cleaned area was then wetted slightly. This was done to allow a clear imprint of the tire to be obtained.

c) Carbon powder was applied to the prepared tire area with a dry household sponge.

d) The tire was rotated so that the prepared area was at the bottom of the tire.

e) Load cells were placed under each tire with the yellow markings aligned with the centre of the tire (Figure A.1). The static weight measurements were made with the use load cell assemblies, and a Campbell Scientific CR-10X data logger. A load cell assembly is comprised of a three thousand pound capacity Futek load cell as seen in Figure A.1, and an adaptor plate. The plates were 12 in. x 12 in. x ¾ in. steel plate with a fine threaded bolt welded at its centre. The welds were made in the BMT FTL welding shop. A typical weld is seen in Figure A.2 and the assembly is shown in Figures A.3a and A.3b. Care was taken to ensure that the instrumentation was placed in the prescribed order:
   i. LC1 – Front passenger
   ii. LC2 – Front driver
   iii. LC3 – Rear passenger
   iv. LC4 – Rear driver

   Note: Once the tires have been turned with the carbon powder facing downward, engaging the parking brake is generally recommended.

f) One sheet of print paper was placed under each tire on the load cell plates.

g) Zero readings for each load cell were recorded.

h) The vehicle was lowered onto the four load cell assemblies.

i) The vehicle weight was recorded when all of the vehicle's weight was supported by the four load cells.

j) The vehicle was then raised. The tire imprints were retrieved by taking them off the load plates.

k) The tire imprints were sealed with permanent sealing spray and allowed to dry.

l) The four tire imprints for each vehicle were labeled and stored in a sealed envelope.

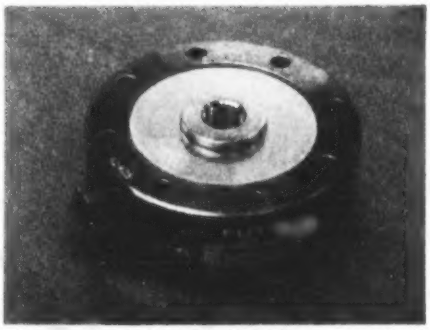


Figure A.1 Futek 3000 lb. Load Cell

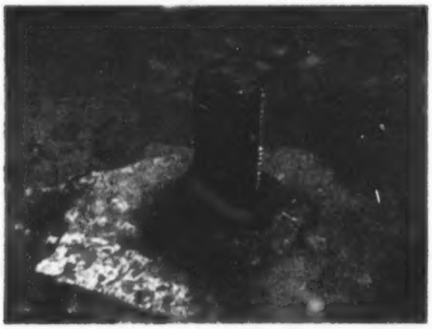


Figure A.2 Adaptor Welded Bolt

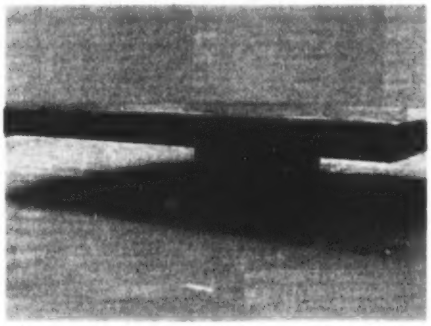


Figure A.3(a) Side Isometric View

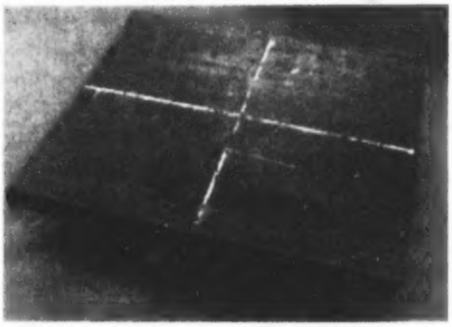


Figure A.3(b) Top Isometric View

APPENDIX B

RAW DATA FOR THE CRFI ASSURANCE TESTS

APPENDIX B.1

RAW DATA TABLES FOR CIRCUIT 1

Note: The test matrix included tests with the operators switched. This was done to allow the effect of different operators to be evaluated. Except for the airport 5 data, the odd-numbered data sets (Runs 1, 3, and 5) were collected using the "original" systems, with the site operator running the site vehicle, and D. Booth running the Transport Canada system. The even-numbered data sets (Runs 2, 4, and 6) were collected by switching operators.

At airport 5, runs 1, 2, 3, 4, and 6 were done with "original" systems. The operators were switched for runs 5 and 7.

Airport 1, Circuit 1

Date:	January 14, 2003			Level Time:		8:05												
Location:	Runway						Runway						Runway					
Surface:	light dusted snow on dry pavement						Pure ice, light dusting of snow						compacted snow w/little sand, loose snow					
Tair (°C)	-23.5						-23.5						-23.5					
Tground (°C)	-22.6						-23.2						-22.4					
Wind Temperature																		
Wind Direction																		
Operator:	TC		Site	Site		TC	TC		Site	Site		TC	TC		Site	Site		TC
ERD type:	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site
Reading No.																		
1	0.55	0.44	0.58	0.47	0.55	0.51	0.09	0.11	0.11	0.09	0.08	0.11	0.33	0.28	0.3	0.31	0.23	0.3
2	0.53	0.46	0.58	0.5	0.43	0.55	0.1	0.09	0.11	0.09	0.08	0.11	0.3	0.22	0.32	0.33	0.25	0.29
3	0.63	0.47	0.57	0.5	0.44	0.52	0.1	0.1	0.12	0.1	C	0.12	0.31	0.27	0.3	0.32	0.25	0.33
4	0.59	0.47	0.55	0.56	0.49	0.53	0.11	0.1	0.13	0.11	C	0.12	0.32	0.28	0.3	0.33	0.26	0.33
5	0.52	0.53	0.5	0.5	0.42	C	0.09	0.09	0.11	0.1	0.07	0.11	0.34	0.28	0.31	0.29	0.22	0.34
6	0.59	0.47	0.58	0.62	0.49	0.59	0.1	0.09	0.11	0.08	0.07	0.11	0.34	0.31	0.3	0.29	0.23	0.33
7	0.54	0.46	0.54	0.57	0.44	0.55	0.13	0.1	0.12	0.09	0.08	0.13	0.33	0.31	0.33	0.3	0.25	0.32
8	0.57	0.44	0.6	0.59	0.47	0.5	0.1	0.11	0.13	0.1	0.08	0.13	0.32	0.27	0.32	0.29	0.24	0.32
9	0.52	0.44	0.53	0.56	0.49	0.54	0.1	0.09	0.11	0.1	0.07	0.12	0.32	0.3	0.31	0.3	0.27	0.33
10	0.58	0.45	0.52	0.56	0.52	0.57	0.1	0.09	0.11	0.09	0.07	0.12	0.34	0.29	0.31	0.29	0.24	0.33
11	0.47	0.38	0.52	0.63	0.52	0.5	0.1	0.1	0.13	0.1	0.09	0.12	0.33	0.28	0.31	0.33	0.27	0.34
12	0.55	0.43	0.55	0.59	0.46	0.53	0.11	0.1	0.12	0.09	0.08	0.12	0.31	0.27	0.32	0.32	0.27	0.34
13	0.46	0.42	0.54	0.52	0.52	0.57	0.09	0.1	0.11	0.09	0.07	0.12	0.33	0.29	0.32	0.31	0.24	0.35
14	0.58	0.45	0.5	C	0.53	0.58	0.1	0.09	0.11	0.08	0.07	0.11	0.31	0.28	0.35	0.26	0.27	0.34
15	0.53	0.46	0.56	0.62	0.52	0.51	0.11	0.09	0.12	0.09	0.08	0.12	0.38	0.28	0.34	0.32	0.27	0.33
16	0.57	0.46	0.57	0.68	0.53	0.55	0.11	0.1	0.12	0.1	0.09	0.12	0.33	0.27	0.33	0.36	0.26	0.32
17				0.66	0.49	0.57				0.08	0.07	0.11	0.31	0.27	0.32	0.36	0.26	0.34
18				0.56	0.48	0.63				0.1	0.08	0.11				0.31	0.24	0.33
19																		
20																		
AVG	0.549	0.452	0.549	0.570	0.488	0.547	0.103	0.097	0.117	0.093	0.077	0.118	0.326	0.279	0.318	0.312	0.251	0.330

*C: Cancellation

Airport 2, Circuit 1

Date:	January 14, 2003			Level Time:8:16														
Location:	Runway						Runway						Runway					
Surface:	packed snow						sanded packed snow (patchy spots)						packed snow, over ice with patchy sand on shoulder					
Tair (°C)	-23.7						-23.2						-20.9					
Tground (°C)	-21.9						-21.9						-20.7					
Wind Speed:																		
Wind Direction:																		
Operator:	TC		Site	Site		TC	TC		Site	Site		TC	TC		Site	Site		TC
ERD type:	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site
Reading No.																		
1	0.26	0.26	0.2	0.27	0.23	0.24	0.27	0.24	0.26	0.26	0.24	0.26	0.27	0.24	0.22	0.35	0.27	0.35
2	0.29	0.28	0.22	0.27	0.24	0.2	0.37	0.36	0.38	0.39	0.35	C	0.29	0.3	0.24	0.27	0.25	0.26
3	0.31	0.29	0.22	0.23	0.23	0.23	0.32	0.33	0.3	0.36	0.32	0.31	0.34	0.24	0.3	0.28	0.24	0.28
4	0.27	0.28	0.25	0.28	0.22	0.26	0.35	0.3	0.31	0.3	0.26	0.32	0.32	0.28	0.25	0.24	0.21	0.26
5	0.3	0.26	0.22	0.29	0.23	0.23	0.33	0.3	0.23	C	0.28	0.29	0.25	0.28	0.23	0.31	0.22	0.25
6	C	0.27	0.24	0.31	0.28	0.18	0.35	0.3	0.29	0.25	0.23	0.25	0.4	0.34	0.29	0.28	0.24	0.28
7	0.33	0.27	0.26	0.27	0.22	0.27	0.3	0.27	0.28	C	0.24	0.27	C	0.32	0.28	0.31	0.22	0.26
8	0.25	0.21	0.2	0.34	0.29	0.29	0.26	0.24	0.22	0.37	0.32	0.41	0.28	0.25	0.24	0.26	0.22	0.28
9	0.23	0.21	0.2	0.32	0.24	0.28	0.35	0.3	0.24	0.42	0.33	0.34	0.26	0.23	0.28	0.4	0.32	0.35
10	0.26	0.22	0.18	0.3	0.26	0.23	0.39	0.37	0.32	0.23	0.21	0.3	0.34	0.29	0.25	0.24	0.23	0.24
11	0.25	0.27	0.21	0.23	0.22	0.26	0.26	0.29	0.27	0.26	0.22	0.23	0.22	0.23	0.23	0.24	0.21	0.22
12	0.29	0.24	0.22	0.22	0.2	0.26	0.39	0.33	0.31	0.28	0.23	0.22	0.3	0.29	0.29	0.29	0.24	0.3
13	0.25	0.23	0.21	0.32	0.27	0.28	0.26	0.3	0.3	0.39	0.26	0.31	0.32	0.28	0.32	0.23	0.2	0.24
14	0.24	0.23	0.26	0.26	0.21	0.23	0.27	0.27	0.25	0.31	0.28	0.42	0.28	0.29	0.27	0.31	0.27	0.3
15	C	0.3	0.22	0.16	0.23	0.27	0.2	0.2	0.24	0.34	0.33	0.39	0.28	0.23	0.23	0.38	0.3	0.33
16	0.3	0.27	0.23	C	0.27	0.29	0.28	0.27	0.22	0.32	0.28	0.29	0.21	0.19	0.22		0.23	0.34
17	0.25	0.23	0.19	0.25	0.23	0.29				0.32	0.27	0.28	0.4	0.33	0.29			
18	0.29	0.25	0.23	0.25	0.23	0.25				0.23	0.22	0.21	0.26	0.24	0.24			
19																		
20																		
AVG	0.273	0.254	0.220	0.269	0.239	0.252	0.309	0.292	0.276	0.314	0.271	0.303	0.295	0.269	0.262	0.293	0.242	0.279

*C: Cancellation

Airport 3, Circuit 1

Date:	January 10, 2003		Level Time:			10:54												
Location:	Runway						Taxiway						Runway					
Surface:	1/8 in. Loose snow on ice, some pavement showing						1/8 in. - 1/4 in. Loose snow on packed snow						1/8 in. Loose snow on ice, some pavement showing (same as runs 1 & 2)					
Tair (°C)	-20.5						-17						-16.7					
Tground (°C)	-13.4						-12.9						(-14.3)					
Wind Speed																		
Wind Direction																		
Operator:	TC		Site	TC		Site	TC		Site	Site		TC	TC		Site	Site		TC
ERD type:	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site
Reading No.																		
1	0.32	0.31	0.27	0.31	0.28	0.23	0.32	0.31	0.28	0.31	0.27	0.2	0.25	0.26	0.31	0.34	0.33	0.31
2	0.29	0.28	0.26	0.32	0.26	0.25	0.32	0.31	0.23	0.3	0.28	0.26	0.32	0.28	0.3	0.29	0.25	0.3
3	0.26	0.22	0.22	0.32	0.27	0.2	0.28	0.29	0.27	0.25	0.23	0.22	0.3	0.24	0.3	0.28	0.24	0.35
4	0.31	0.26	0.37	0.26	0.23	0.38	0.32	0.31	0.25	0.32	0.3	0.23	0.21	0.2	0.26	0.28	0.26	0.36
5	0.29	0.3	0.23	0.29	0.22	0.26	0.29	0.29	0.23	0.32	0.3	0.23	0.21	0.17	0.2	C	0.16	0.25
6	0.24	0.21	0.18	0.26	0.23	0.23	0.31	0.29	0.22	0.26	0.22	0.21	C	0.21	0.22	0.2	0.18	0.23
7	0.27	0.27	0.3	0.26	0.24	0.24	0.35	0.3	0.24	0.29	0.26	0.28	0.28	0.26	0.33	0.26	0.24	0.26
8	0.23	0.19	0.22	0.28	0.27	0.24	0.27	0.28	0.2	0.25	0.24	0.15	0.3	0.27	0.23	0.24	0.23	0.21
9	0.23	0.2	0.21	0.3	0.27	0.27	0.3	0.28	0.2	0.26	0.23	0.25	0.33	0.33	0.31	0.3	0.26	0.19
10	0.34	0.29	C	0.33	0.28	0.32	0.25	0.24	0.21	0.27	0.26	0.21	0.31	0.31	0.33	0.31	0.28	0.29
11	0.24	0.22	0.23	C	0.24	0.25	0.28	0.26	0.23	0.26	0.25	0.19	0.33	0.31	C	0.28	0.28	0.27
12	0.26	0.24	0.21	0.2	0.18	0.23	0.29	0.26	0.25	0.28	0.26	0.18	0.26	0.23	C	0.23	0.2	0.19
13	0.19	0.2	0.22	0.34	0.3	0.24	0.28	0.28	0.19	0.24	0.25	0.18	0.29	0.29	0.29	0.23	0.2	0.25
14	0.23	0.23	0.23	0.32	0.28	0.27	0.28	0.25	0.21	0.29	0.27	0.23	0.32	0.33	0.33	0.27	0.24	0.34
15	C	0.27	0.2	0.3	0.28	0.29	0.3	0.28	0.22	0.25	0.22	0.2	0.35	0.32	0.28	0.28	0.21	C
16	0.32	0.34	0.29	0.25	0.23	0.28							0.21	0.21	0.26	0.32	0.26	0.33
17	0.29	0.33	0.28	0.31	0.28	0.25							0.26	0.22	0.24	0.25	0.21	0.35
18	0.33	0.32	0.19	0.15	0.13	0.19							0.15	0.15	0.27	0.2	0.16	0.26
19	0.23	0.19	0.21										0.21	0.17	0.22	0.21	0.21	0.24
20																		
AVG	0.27	0.26	0.24	0.28	0.25	0.26	0.30	0.28	0.23	0.28	0.26	0.22	0.27	0.25	0.27	0.27	0.23	0.27

*C: Cancellation

Airport 4, Circuit 1

Date:	January 11, 2003		Level Time: 11:03															
Location:	Taxiway						Runway											
Surface:	1/2 in. Loose snow over ice - mid taxiway has more snow/less ice giving slightly higher readings on each pass.												Just swept; almost bare					
Tair (°C)	-6.6 (-7)																	
Tground (°C)	-5.6																	
Wind Direction:																		
Wind Speed:																		
Operator:	TC		Site	TC		Site	TC		Site	Site		TC	TC		Site	Site		TC
ERD type:	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site
Reading No.																		
1	0.15	0.16	0.19	C	0.14	C	0.19	0.19	0.21	0.23	0.25	0.21	0.41	C	C	0.44	0.3	0.4
2	0.18	0.19	0.22	0.15	0.16	0.14	0.24	0.26	0.24	0.26	0.21	0.31	0.47	0.37	0.34	0.47	0.34	0.5
3	0.2	0.18	0.22	0.18	C	0.16	0.23	0.21	0.2	0.21	0.19	0.21	0.54	0.42	0.46	0.25	0.22	0.51
4	0.21	0.19	0.19	0.18	C	0.18	0.2	0.19	0.2	0.19	0.16	0.19	0.43	0.41	C	0.27	0.22	0.39
5	0.19	0.19	0.19	0.17	0.15	0.21	0.19	0.17	0.19	0.17	0.16	0.2	C	C	0.41	0.23	0.2	0.37
6	0.16	0.15	0.18	0.18	0.16	0.2	0.19	0.18	0.22	0.19	0.18	0.2	0.45	0.48	0.43	0.3	0.23	0.47
7	0.15	0.14	0.19	C	0.17	0.16	0.21	0.18	0.2	0.18	0.17	0.19	0.44	C	0.46	C	0.25	0.37
8	0.19	0.16	0.2	0.16	0.15	0.18	0.2	0.19	0.2	0.19	0.16	0.2	0.22	0.23	0.5	0.23	0.19	0.52
9	0.19	0.17	0.23	0.17	0.17	0.21	0.19	0.19	0.19	0.2	0.17	0.21	0.26	0.33	0.44	0.47	0.34	0.53
10	0.19	0.17	0.2	0.23	0.21	0.19	0.23	0.2	0.22	0.18	0.15	0.24	C	C	0.42	0.38	0.31	0.56
11	0.19	0.19	0.19	0.2	0.18	0.2	0.19	0.18	0.2	0.2	0.16	0.2	0.53	0.54	0.35	C	0.34	0.49
12	0.19	0.16	0.21	0.2	0.17	0.15	0.19	0.19	0.21	0.18	0.15	0.25	0.43	C	0.31	0.38	0.27	0.53
13	0.18	0.18	0.18	0.18	0.16	0.19	0.17	0.18	0.21	0.18	0.17	0.22	0.22	0.19	0.34	0.44	0.34	0.29
14	0.21	0.17	0.2	0.17	0.16	0.19	0.17	0.16	0.2	0.18	0.16	0.23	0.23	0.23	0.36	0.3	0.24	0.42
15	0.19	0.17	0.23	0.18	0.16	0.18	0.18	0.18	0.2				0.3	0.24	0.33	0.38	0.31	C
16	0.2	0.2	0.2	0.19	0.18	0.18	0.19	0.17	0.21				0.2	0.25	0.34	0.45	0.34	0.56
17	0.2	0.2	0.21	0.17	0.16	0.2							0.38	0.46	0.38	0.31	0.25	0.41
18	0.16	0.16	0.2	0.18	0.16	0.21							0.27	0.4				
19				0.17	0.15								0.29	0.32				
20				0.18	0.18													
AVG	0.185	0.174	0.202	0.180	0.165	0.184	0.198	0.189	0.206	0.196	0.174	0.219	0.357	0.348	0.391	0.353	0.276	0.461

*C: Cancellation

Airport 5, Circuit 1

Date:	January 9, 2003	Level Time:	13:00							Date:	January 13, 2003			Level Time:	10:36						
Tair (°C)	-13 to -11									-12 (-15.6)											
Tground (°C)	-6.9			-9.4			-9.9			-12, -12.5						-15.6					
Wind Speed	40									17 - 22						17 - 22					
Wind Direction	5									310-360						310-360					
Location:	Runway (off centre)			Runway (Edge)			Runway			Runway						Runway					
Surface:	Sanded ice formed from packed snow			Ice from packed snow (no sand)			Ice			Fresh swept, light snow patch, dusting blowing snow						fresh plowed/ pure Ice					
Operator:	TC		Site	TC		Site	TC		Site	TC		Site	Site		TC	TC		Site	Site		TC
ERD type:	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site	Mk II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mk III	Site
Reading No.																					
1	0.45	0.43	0.44	0.17	0.15	0.15	0.15	0.15	0.2	0.64	0.49	0.77	0.55	0.57	0.38	0.14	0.17	0.17	C	0.12	0.21
2	0.32	0.29	0.44	0.21	0.19	0.16	0.17	0.18	0.22	0.69	0.66	0.85	0.74	0.62	0.82	0.14	0.14	0.14	0.25	0.22	0.13
3	0.26	0.28	0.32	0.2	0.2	0.18	0.17	0.17	0.18	0.66	0.57	0.82	0.71	0.71	0.83	0.11	0.11	0.18	0.11	0.09	0.11
4	0.48	0.48	0.33	0.2	0.16	0.15	0.22	0.18	0.19	0.75	0.74	0.77	0.76	0.62	0.84	0.25	0.22	0.19	0.16	0.16	0.11
5	0.34	0.34	0.42	0.14	0.14	0.15	0.22	0.22	0.26	0.72	0.59	0.86	0.65	0.57	0.8	0.11	0.11	0.14	C	0.14	0.13
6	0.3	0.37	0.42	0.21	0.16	0.15	0.22	0.22	0.21	0.63	0.64	0.73	0.77	0.63	0.76	0.23	0.16	0.16	0.21	0.18	0.16
7	0.3	0.24	0.39	C	0.14	0.14	0.19	0.2	0.2	0.69	0.57	0.75	0.71	0.6	0.73	0.15	0.15	0.13	0.09	0.1	0.12
8	0.24	0.22	0.33	0.15	0.15	0.17	0.2	0.17	0.16	0.51	0.48	0.68	0.72	0.59	0.86	C	0.12	0.16	0.12	0.11	0.12
9	0.41	0.4	0.38	0.2	0.2	0.22	0.14	0.14	0.18	0.74	0.52	0.57	0.71	0.6	0.66	C	0.14	0.18	0.17	0.18	0.14
10	0.35	0.34	0.33	0.18	0.17	0.17	0.15	0.14	0.21	0.75	0.75	0.78	0.69	0.71	0.87	0.16	0.13	0.16	0.13	0.11	0.13
11	0.38	0.37	0.24	0.14	0.15	0.15	0.19	0.2	0.19	0.75	0.6	0.79	0.7	0.69	0.88	0.12	0.14	0.15	0.25	0.21	0.18
12	0.31	0.28	0.37	0.15	0.16	0.16	0.14	0.14	0.16	0.72	0.72	0.72	0.79	0.6	0.84	0.2	0.16	0.16	0.22	0.16	0.17
13	0.36	0.35	0.42	0.17	0.19	0.15	C	C	0.22	0.76	0.61	0.72	0.72	0.6	0.86	0.13	0.13	0.15	0.11	0.11	0.12
14	0.28	0.32	0.46	0.19	0.18	0.19	0.15	0.15	0.2	0.76	0.6	0.81	0.75	0.74	0.82	0.18	0.15	0.19	C	0.14	0.15
15	0.29	0.27	0.44	0.17	0.15	0.16	0.15	0.16	0.15	0.71	0.59	0.76	0.76	0.63	0.84	0.16	0.12	0.29	C	0.12	0.14
16																0.11	0.11	0.14	0.1	0.12	0.13
17																			0.12	0.12	0.13
18																			0.12	0.12	0.14
19																			0.16	0.12	0.22
20																			0.17	0.18	0.26
AVG	0.34	0.33	0.38	0.18	0.17	0.16	0.18	0.17	0.20	0.70	0.61	0.76	0.72	0.63	0.79	0.16	0.14	0.17	0.16	0.14	0.15

*C: Cancellation

APPENDIX B.1

RAW DATA TABLES FOR CIRCUIT 2

Airport 1, Circuit 2

Date:	February 4, 2003			Level Time:		13:04												
Location:	Runway						Runway						Runway					
Surface:	Bare with snow patches (very windy, plow continuous to prevent high drifts for us)						Packed snow & ice due to freezing rain 3 days earlier. (drifts plowed away)						Blowing snow over ice					
Tair (°C)	-15.9						-15.9						-16.6					
Tground (°C)	-14.9						-15						-16					
Wind Speed	25 knots (gusting 32)						25 knots (gusting 32)						25 knots (gusting 32)					
Wind Direction	340						340						340					
Operator:	TC		Site	Site		TC	TC		Site	Site		TC	TC		Site	Site		TC
ERD type:	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site
Reading No.																		
1	0.42	0.46	0.45	0.39	0.37	0.41	Mark II data lost on print - "Set Zero" message appeared. Due to weather we will not repeat this test. The Blazer was originally calibrated on garage apron: Mark IIIs will not be recalibrated. Mark II cal'ed on 17-35 button @17end.	0.26	0.25	0.21	0.25	0.23	0.11	0.10	0.14	0.12	0.10	0.14
2	0.46	0.41	0.42	0.36	0.36	0.43		0.28	0.29	0.18	0.22	0.24	0.11	0.10	0.1	0.10	0.10	0.15
3	0.46	0.46	0.37	0.41	0.42	0.42		0.28	0.3	0.24	0.22	0.23	C	0.11	0.12	0.13	0.10	0.13
4	0.38	0.38	0.44	0.4	0.37	0.43		0.25	0.27	0.19	0.22	0.27	0.13	0.12	0.15	0.10	0.09	0.14
5	0.43	0.45	0.44	0.41	0.41	0.39		0.28	0.3	0.24	0.22	0.2	0.11	0.10	0.12	C	0.10	0.16
6	0.47	0.49	0.39	0.36	0.37	0.28		0.27	0.28	0.28	0.22	0.26	0.11	0.10	0.12	0.10	0.10	0.15
7	0.42	0.41	0.44	0.46	C	0.4		0.28	0.29	0.27	0.22	0.23	0.12	0.11	0.13	0.12	0.11	0.14
8	0.42	0.43	0.41	0.36	0.38	0.43		0.28	0.28	0.22	0.22	0.22	0.11	0.11	0.13	0.11	0.10	0.14
9	0.36	0.37	0.39	0.45	0.4	0.36		0.31	0.3	0.25	0.22	0.24	0.11	0.11	0.12	0.11	0.12	0.15
10	0.33	0.46	0.37	0.42	0.41	0.41		0.21	0.23	C	0.22	0.2	0.11	0.10	0.12	0.10	0.11	0.15
11	0.5	0.51	0.46	0.44	0.4	0.39		0.29	0.31	0.28	0.22	0.26	0.12	0.11	0.13	0.12	0.11	0.13
12	0.44	0.46	0.41	0.4	0.41	0.4		0.29	0.28	0.25	0.22	0.27	C	0.11	0.15	0.10	0.09	0.14
13	0.36	0.46	0.37	0.44	0.45	0.47		0.23	0.27	0.23	0.22	0.26	0.12	0.11	0.14	0.11	0.11	0.15
14	0.35	0.44	C	0.47	C	C		0.28	0.27	0.28	0.22	0.24	0.11	0.10	0.11	0.12	0.11	0.15
15	0.3	0.29	C	0.49	C	0.57		0.24	0.26	C	0.22	0.22	0.12	0.11	0.14	0.12	0.10	0.14
16	0.5	0.49	C	0.43	0.43	0.52		0.28	0.31	0.26	0.22	0.25	0.13	0.12	0.14	0.11	0.11	0.13
17	0.54	0.53	0.51	0.45	0.48	0.55		0.29	0.27	0.23	0.22	0.25	0.11	0.10	0.12	0.10	0.08	0.15
18	0.58	0.59	0.48	C	0.52	0.51		0.26	0.31	0.25	0.22	0.26	0.09	0.10	0.12	0.11	0.10	0.14
19	0.47	0.47	0.43	0.48	0.45	0.52												
20	0.46	0.46	C	0.43	0.42	0.44												
21	0.42	0.42	0.47															
22	0.45	0.45	0.39															
AVG	0.433	0.450	0.424	0.424	0.415	0.438	NA	0.270	0.282	0.241	0.222	0.241	0.114	0.107	0.128	0.111	0.102	0.143

*C: Cancellation

Airport 2, Circuit 2

Date:	February 4, 2003		Level Time: 9:29									
Location	Ramp						Runway					
Surface:	Compact snow						Sandy packed snow over ice (outside lights)					
Tair (°C)	-24.4						-23.4					
Tground (°C)	-23.5						-17.2					
Wind Speed	10 gusting 20 knots						10 gusting 20 knots					
Wind Direction	90 (West)						90 (West)					
Operator:	TC		Site	TC		Site	TC		Site	TC		Site
ERD type:	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site
Reading No.												
1	0.16	0.13	0.13	C	0.13	0.09	0.25	0.23	0.16	0.19	0.17	0.12
2	0.16	0.15	0.15	0.08	C	0.09	0.21	0.22	0.17	C	0.18	0.09
3	0.15	0.13	0.12	0.14	0.12	0.09	0.24	0.24	0.18	0.32	0.31	0.2
4	C	0.14	0.13	0.12	0.12	0.08	0.23	0.21	C	0.13	0.17	0.12
5	0.13	0.14	0.13	0.13	0.1	0.1	0.25	0.24	0.18	0.19	0.18	0.14
6	0.14	0.14	0.13	0.17	0.12	0.07	0.23	0.22	C	0.21	0.2	0.13
7	0.14	0.13	0.11	0.13	0.16	0.1	0.22	0.21	0.19	0.18	0.18	0.15
8	0.1	0.11	0.12	0.13	0.11	0.08	0.25	0.25	0.15	0.14	0.12	0.13
9	0.15	0.14	0.12	0.12	0.15	0.11	0.29	0.26	C	0.2	0.2	0.18
10	C	0.13	0.12	0.12	0.12	0.1	0.22	0.21	0.17	0.16	0.2	0.12
11	C	0.15	0.12	0.12	0.11	0.1	0.26	0.24	0.16	0.21	0.2	0.15
12	0.21	0.16	0.14	0.13	0.13	0.1	0.22	0.18	0.18	0.28	0.25	0.19
13	C	0.12	C	0.12	0.12	C	0.19	0.18	0.12	0.21	0.2	0.19
14	0.13	0.17	0.11	0.13	0.1	0.08	0.2	0.2	0.16	0.18	0.17	0.11
15	C	0.12	0.09	0.11	0.1	0.1	0.22	0.17	0.12	0.23	0.21	0.14
16	0.14	0.13	0.1	0.13	0.11	0.11	0.19	0.18	0.16	0.18	0.16	0.08
17	C	0.14	0.11	0.12	0.12	0.07	C	0.17	0.12	0.24	0.24	0.19
18	C	0.12	0.12	0.12		0.1	0.19	0.16	0.1	0.23	0.21	0.15
19	C	C	C									
20	0.14	0.12	0.11									
21	0.17	C	0.11									
22	C	0.11	0.1									
23	0.14	0.12	0.09									
AVG	0.148	0.133	0.117	0.125	0.120	0.092	0.227	0.209	0.155	0.205	0.197	0.143

*C: Cancellation

Airport 3, Circuit 2

Date:	February 4, 2003			Level Time: 8:05														
Location:	Taxiway						Runway						Taxiway					
Surface:	1/4 in. loose snow over packed snow						Packed snow over ice						1/4 in. loose snow over packed snow					
Tair (°C)	-18.3						-18.2						-15.9					
Tground (°C)	-17						-17.2						-15					
Wind Speed	10						10						10					
Wind Direction	50						50						50					
Operator:	TC		Site	Site		TC	TC		Site	Site		TC	TC		Site	Site		TC
ERD type:	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site
Reading No.																		
1	0.32	0.3	0.27	0.29	0.32	0.22	0.21	0.2	0.11	0.17	0.17	0.11	C	0.26	0.23	0.34	0.34	
2	0.32	0.29	0.25	0.34	0.33	0.24	0.21	0.23	0.14	0.24	0.22	0.11	0.3	0.28	0.24	0.38	0.37	
3	0.36	0.35	0.21	0.25	0.26	0.18	0.2	0.23	0.13	0.24	0.23	0.13	0.18	0.24	0.22	C	0.36	
4	0.37	0.36	0.23	0.26	0.3	0.16	0.19	0.23	C	C	0.21	0.11	0.31	0.27	0.21	0.34	0.34	
5	0.34	0.34	0.23	0.26	0.28	0.2	0.21	0.24	0.11	0.2	0.21	0.12	0.32	0.28	0.28	0.33	0.32	
6	0.31	0.31	0.21	0.27	0.26	0.24	0.3	0.28	0.1	0.22	0.22	0.12	0.31	0.28	0.28			
7	0.25	0.25	0.24	0.32	0.32	0.18	0.28	0.27	0.11	0.19	0.2	0.12	0.23	0.24	0.23			
8	0.33	0.31	0.24	0.32	0.29	0.21	C	0.27	0.1	0.23	0.22	0.13	C	0.29	0.23			
9	0.27	0.33	0.22	0.28	0.27	0.21	0.15	0.22	0.13	0.18	0.18	0.12	0.33	0.31	0.25			
10	0.24	0.29	0.22	0.28	0.26	0.23	0.18	0.18	0.11	0.2	0.21	0.1	0.23	0.22	0.18			
11	0.25	0.29	0.2	0.32	0.3	0.2	C	0.23	0.14	0.2	0.2	0.09	0.23	0.2	0.17			
12	0.31	0.31	0.19	0.27	0.26	0.22	0.18	0.24	0.13	0.18	0.18	0.09	C	0.2	0.17			
13	0.3	0.26	0.22	0.33	0.31	0.21	0.24	0.24	0.11	0.16	0.18	C	0.26	0.28	0.2			
14	C	0.33	0.22	0.36	0.35	0.2	C	0.19	0.15	0.25	0.19	0.09	0.35	0.31	0.23			
15	0.29	0.33	0.2	0.33	0.32	0.22	0.2	0.21	0.14	0.22	0.22	0.14	0.25	0.25	0.21			
16	0.28	0.33	0.22	0.29	0.29	0.15	0.14	0.14	0.07	0.19	0.18	0.1	0.29	0.26	0.17			
17	C	0.32	0.19	0.24	0.23	0.13	0.22	0.22	0.11	C	0.14	0.1	C	0.26	0.19			
18	0.27	0.24	0.23	0.3	0.28	0.2	0.29	0.27	0.14	0.17	0.17		0.31	0.28	0.22			
19	C	0.31	0.17							0.15	0.13							
20	0.23	0.27	0.17															
21																		
22																		
AVG	0.30	0.31	0.22	0.30	0.29	0.20	0.21	0.23	0.12	0.20	0.19	0.11	0.28	0.26	0.22	0.35	0.35	

*C: Cancellation

Airport 4, Circuit 2

Date:	Feb 10, 2003		Level Time: 13:13									
Location:	Runway						Taxiway					
Surface:	Compact snow with <1/8 in. loose						Packed snow over ice					
T_{air} (°C)	-18						-19					
T_{ground} (°C)	-13.6						-18.3					
Wind Speed												
Wind Direction												
Operator:	TC		Site	Site		TC	TC		Site	Site		TC
ERD type:	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site
Reading No.												
1	0.3	0.28	0.27	0.27	0.26	0.24	0.3	0.26	0.27	0.24	0.22	0.26
2	0.41	0.4	C	0.39	0.37	0.3	0.19	0.18	0.2	0.17	0.16	0.17
3	0.36	0.34	0.3	C	0.3	0.31	0.19	0.17	0.21	0.23	0.18	0.17
4	0.4	0.39	0.3	0.3	0.31	0.29	0.22	0.19	0.2	C	C	0.25
5	0.3	0.37	0.3	0.33	0.37	0.32	0.18	0.16	0.18	0.14	0.12	0.17
6	0.37	0.37	0.27	0.37	0.36	0.3	0.24	0.22	0.22	C	0.12	0.16
7	0.39	0.38	0.29	0.38	0.38	0.31	0.2	0.18	0.2	0.2	0.17	0.19
8	0.38	0.36	0.27	0.33	0.31	0.23	0.21	0.25	0.23	0.22	0.22	0.22
9	0.37	0.37	0.3	0.29	0.29	0.26	0.31	0.3	0.25	0.22	0.23	0.22
10	0.35	0.35	0.3	0.29	0.3	0.31	0.19	0.18	0.17	0.14	0.14	0.12
11	0.37	0.35	0.32	C	0.33	0.31	0.19	0.19	0.25	C	0.12	0.16
12	C	0.32	0.26	0.26	C	0.27	0.17	0.2	0.23	0.15	0.13	0.16
13	0.32	0.31	C	0.32	0.29	0.27	0.2	0.18	0.15	0.16	0.14	0.15
14	0.36	0.35	0.25	0.21	0.17	0.22	0.17	0.19	0.19	0.22	0.23	0.2
15	0.21	0.25	0.21	0.32	0.31	0.25	0.14	0.13	0.18	0.13	0.11	0.17
16	0.36	0.35	0.26	0.27	0.27	0.26	0.2	0.22	0.21	0.23	0.23	0.24
17	0.3	0.33	0.25	0.29	0.31	0.27				0.24	0.18	0.18
18	0.35	0.33	0.29	0.36	0.35	0.29				0.23	0.24	0.17
19										0.29	0.3	0.14
20										0.3	0.3	0.2
21												
22												
23												
AVG	0.347	0.344	0.278	0.311	0.311	0.278	0.206	0.200	0.209	0.206	0.186	0.185

*C: Cancellation

Airport 5, Circuit 2

Date:	Feb 6 2003		Level Time: 18:06									
Location:	Shoulder						Runway (off centre)					
Surface:	<1/8 in. snow over ice						Thin ice with scattered bare and dry patches					
T_{air} (°C)	-17						-17.6					
T_{ground} (°C)	-14.4						-15.6					
Wind Speed	10						10					
Wind Direction	030						030					
Operator:	TC		Site	Site		TC	TC		Site	Site		TC
ERD type:	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site	Mark II	Mark III	Site
Reading No.												
1	0.33	0.31	0.26	0.29	0.26	0.23	0.61	0.61	0.5	0.26	0.26	0.44
2	0.3	0.31	0.23	0.28	0.26	0.25	0.65	0.64	0.49	0.46	0.43	0.24
3	0.34	0.33	0.26	0.32	0.29	0.25	0.74	0.74	0.45	0.3	0.39	0.23
4	0.31	0.29	0.24	0.29	0.27	0.23	0.773	0.71	0.51	0.44	0.39	0.21
5	0.31	0.31	0.24	0.26	0.25	0.22	0.64	0.32	0.5	0.46	0.55	0.29
6	0.29	0.27	0.25	0.25	0.24	0.22	0.44	C	0.45	0.33	0.3	0.26
7	0.3	0.28	0.23	0.19	0.2	C	0.51	0.5	0.35	0.28	0.33	0.2
8	0.27	0.27	0.22	0.31	0.28	0.26	0.57	0.56	0.44	0.33	0.32	0.19
9	0.3	0.28	0.23	0.27	0.26	0.24	0.36	0.37	0.36	0.32	0.3	0.26
10	0.3	0.28	0.22	0.29	0.3	0.24	0.4	0.43	0.41	0.43	0.45	0.42
11	0.33	0.28	0.24	0.3	0.28	0.24	0.51	0.53	0.37	0.36	0.38	0.46
12	0.25	0.24	0.23	0.26	0.24	0.23	0.3	0.3	0.25	0.47	0.44	C
13	0.31	0.28	0.23	0.27	0.25	0.25	0.23	0.25	0.34	0.48	0.47	0.53
14	0.29	0.27	0.23	0.29	0.3	0.24	0.41	0.46	0.39	0.44	0.43	0.45
15	0.25	0.26	0.21	0.33	0.31	0.28	0.26	0.26	0.29	0.48	0.53	0.48
16	0.32	0.29	0.24	0.29	0.28	0.24	0.36	0.38	0.4			
17	0.31	0.3	0.23	0.3	0.28	0.25	0.42	0.38	0.35			
18	0.31	0.29	0.23	0.26	0.25	0.23	0.3	0.32	0.39			
19												
20												
21												
22												
23												
AVG	0.301	0.286	0.234	0.281	0.267	0.241	0.471	0.456	0.402	0.389	0.398	0.333

*C: Cancellation

APPENDIX B.2
RAW DATA CHARTS

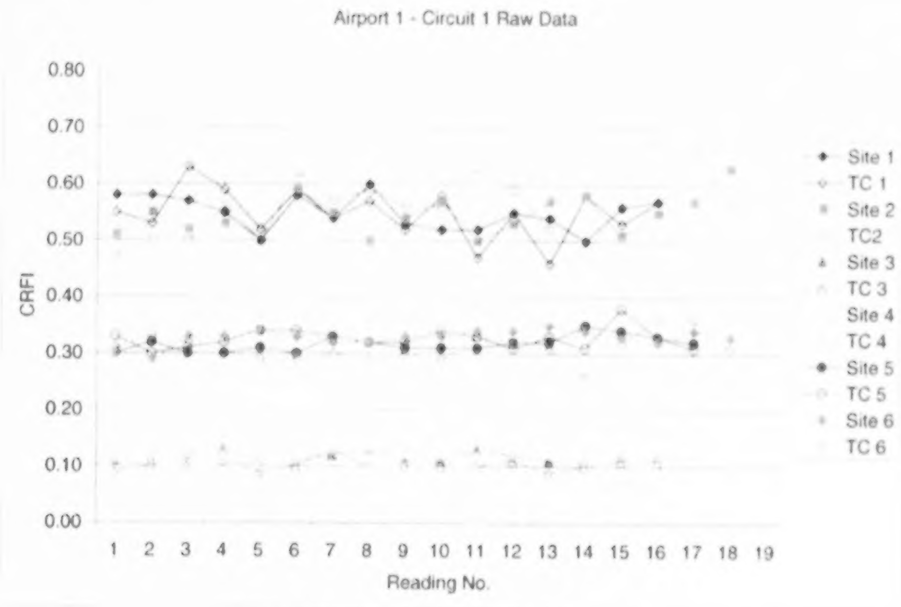


Figure B.1: Airport 1 - Circuit 1

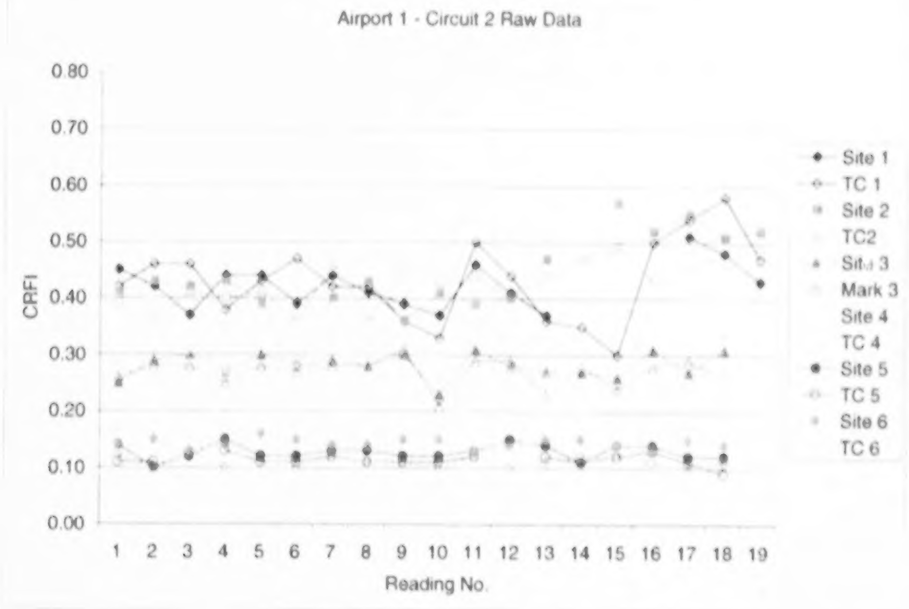


Figure B.2: Airport 1 - Circuit 2

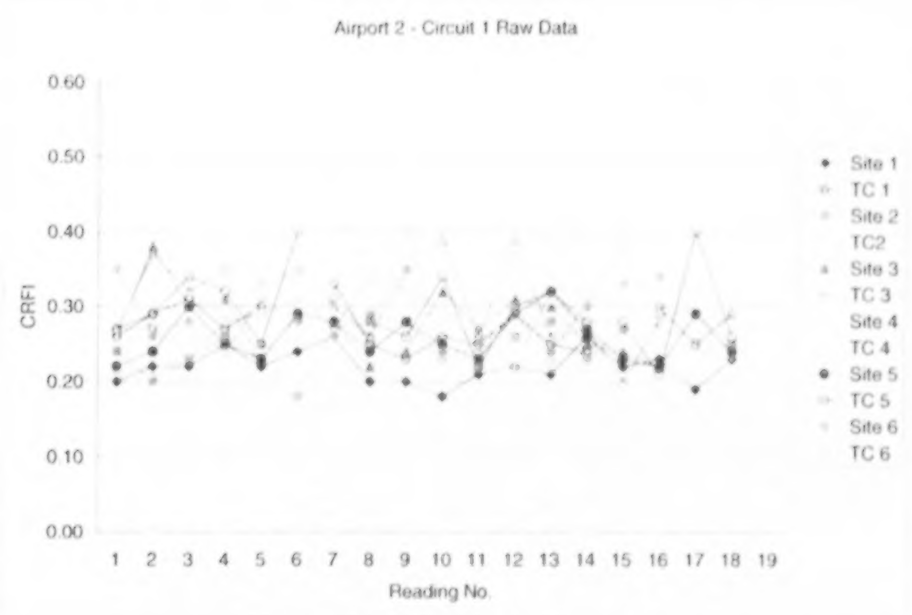


Figure B.3: Airport 2 - Circuit 1

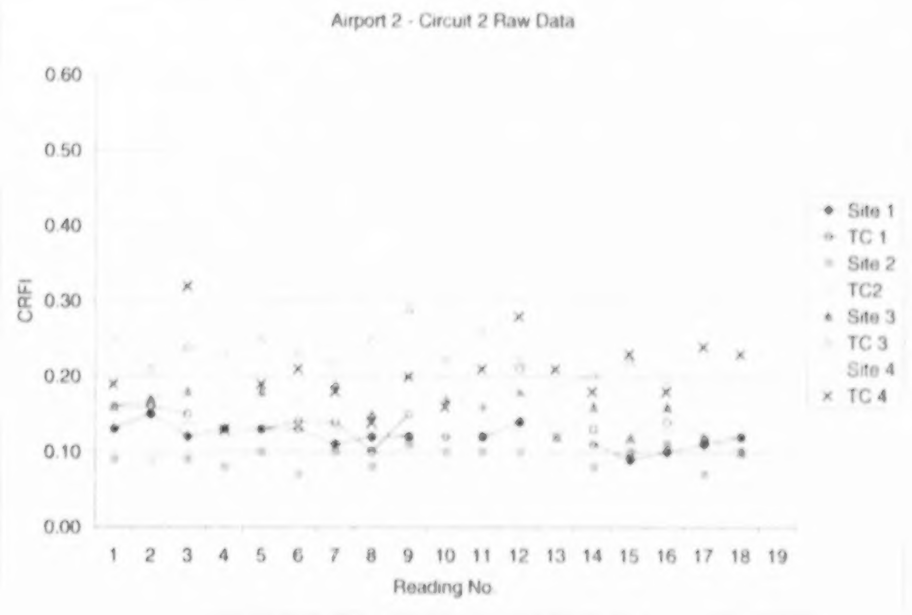


Figure B.4: Airport 2 - Circuit 2

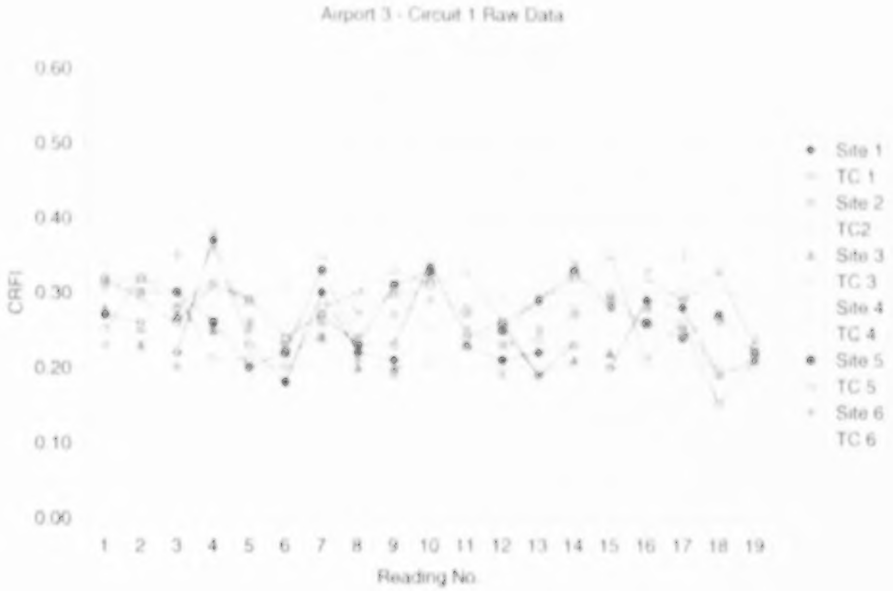


Figure B.5: Airport 3 - Circuit 1

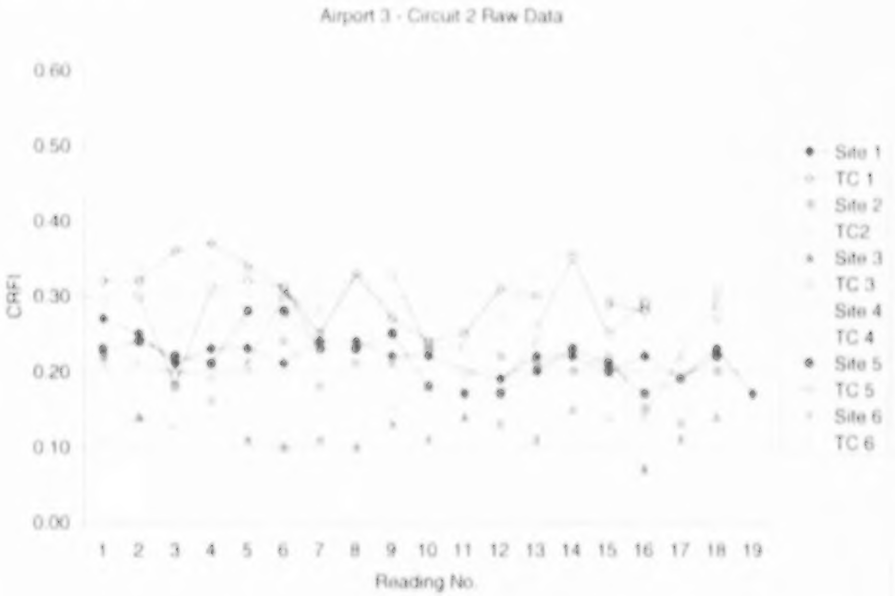


Figure B.6: Airport 3 - Circuit 2

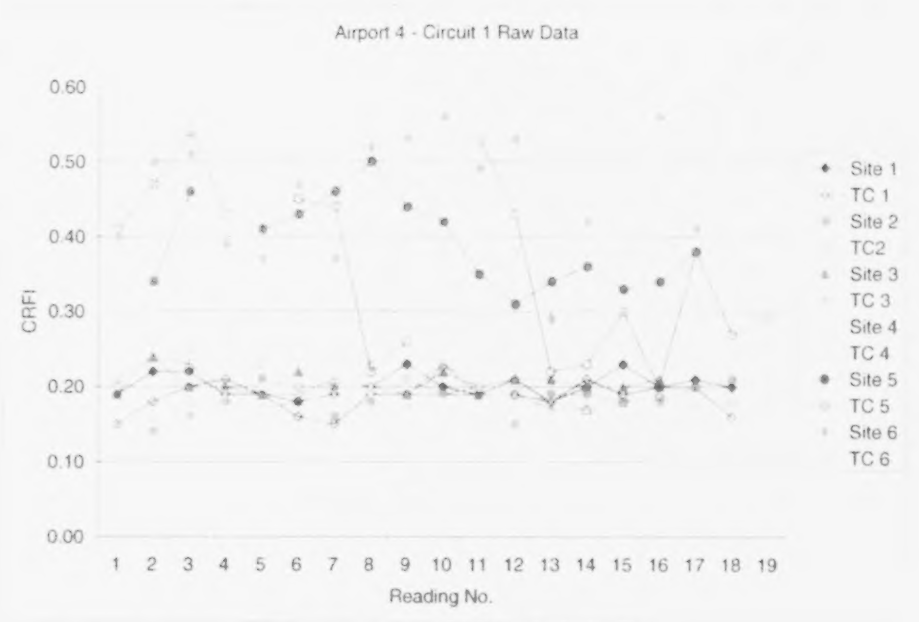


Figure B.7: Airport 4 - Circuit 1

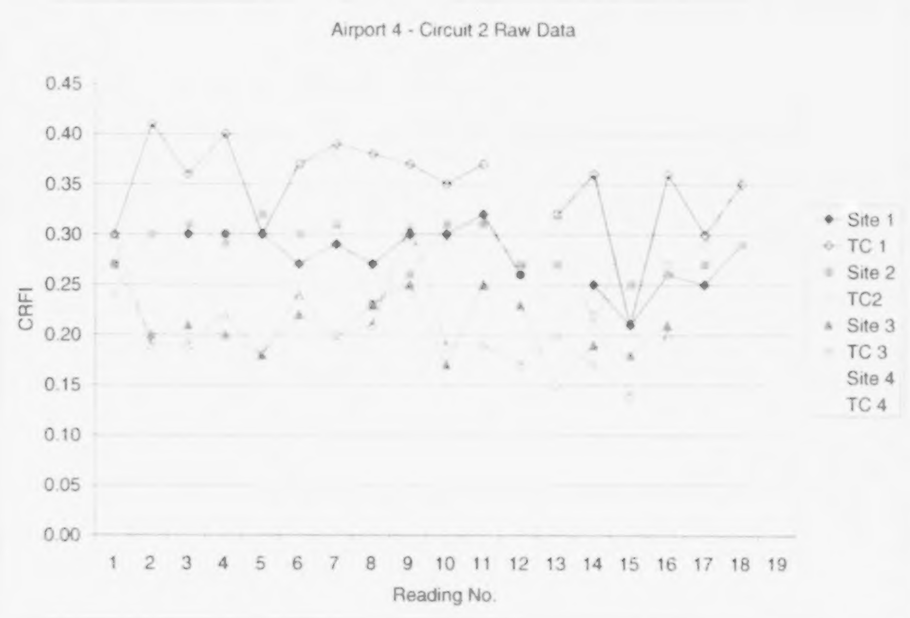


Figure B.8: Airport 4 - Circuit 2

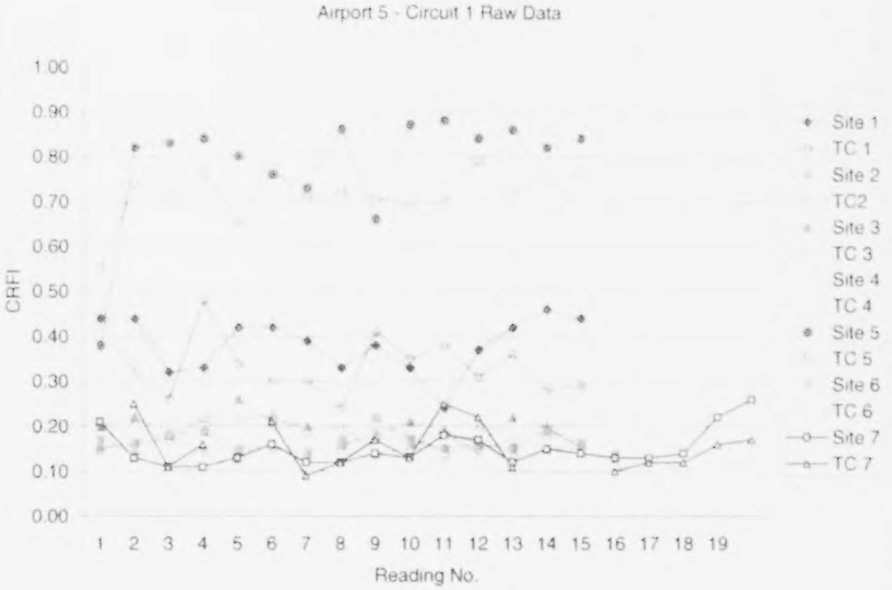


Figure B.9: Airport 5 - Circuit 1

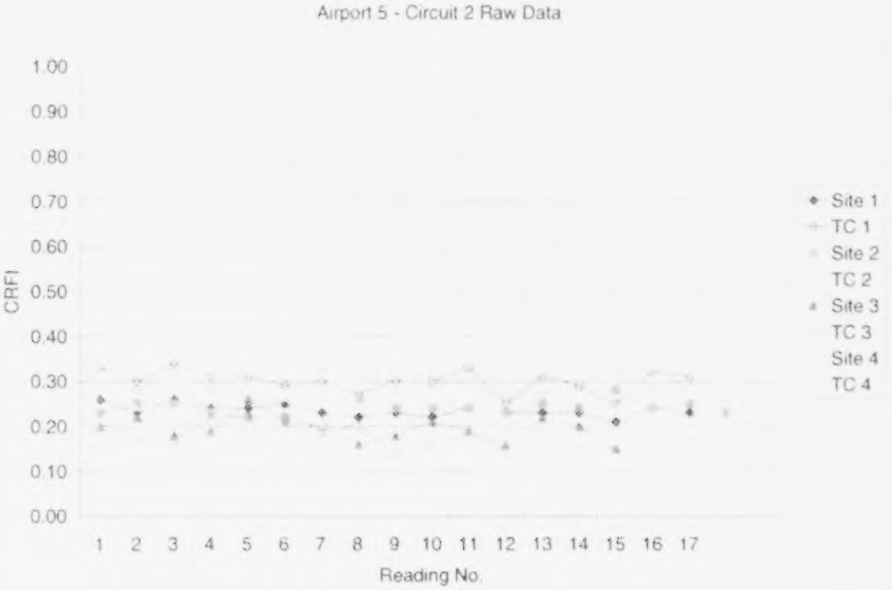
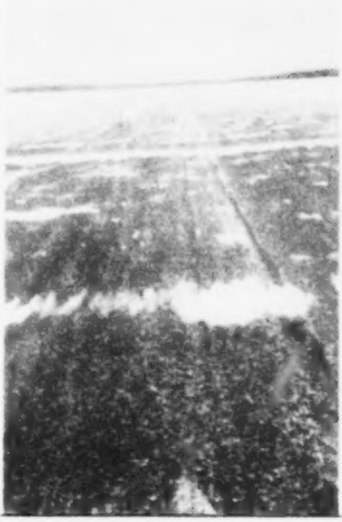
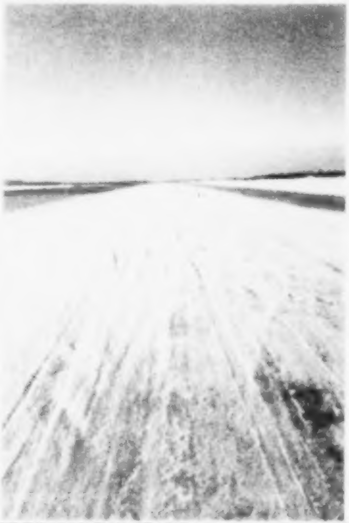
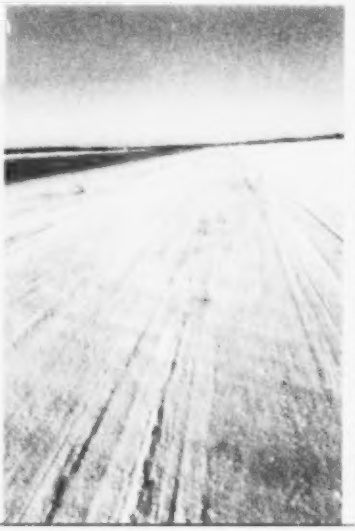
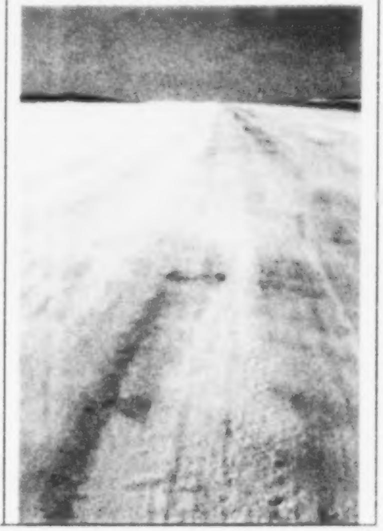
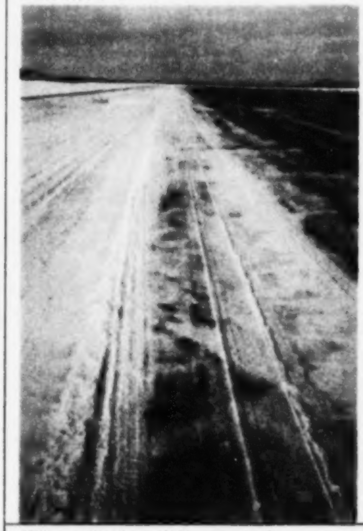
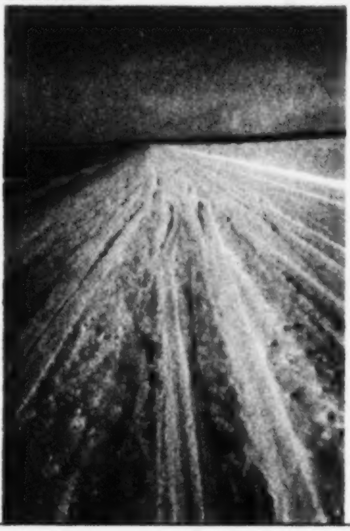


Figure B.10: Airport 5 - Circuit 2

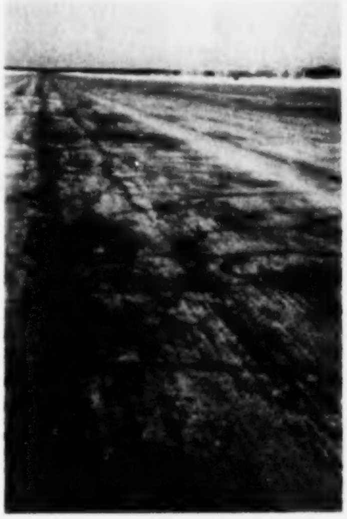
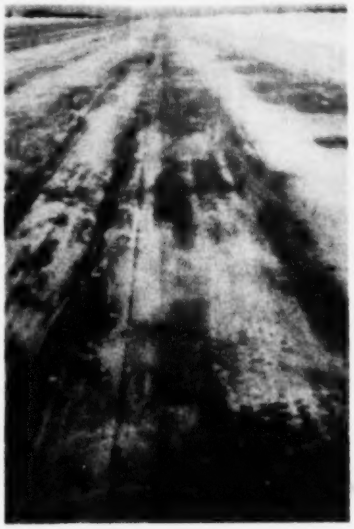
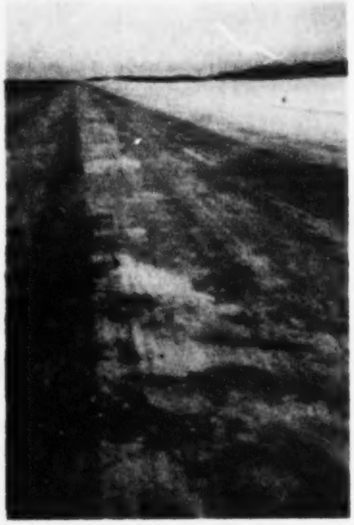
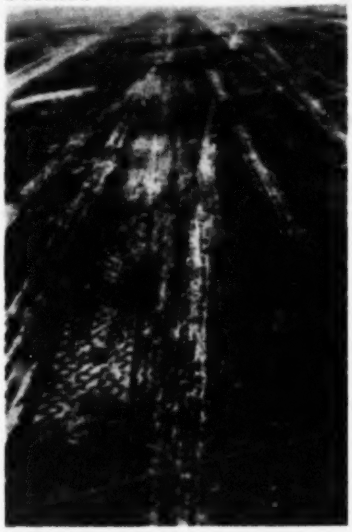
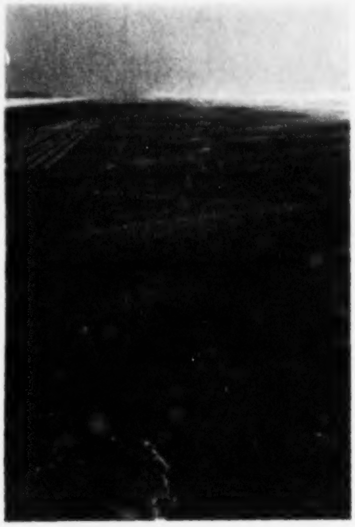
APPENDIX C

TEST SURFACES FOR THE CRFI ASSURANCE TESTS

Circuit 1 – Airport 1		
Surface 1 –	Surface 2 – 	Surface 3 –
Circuit 1 – Airport 2		
Surface 1 	Surface 2 	Surface 3 

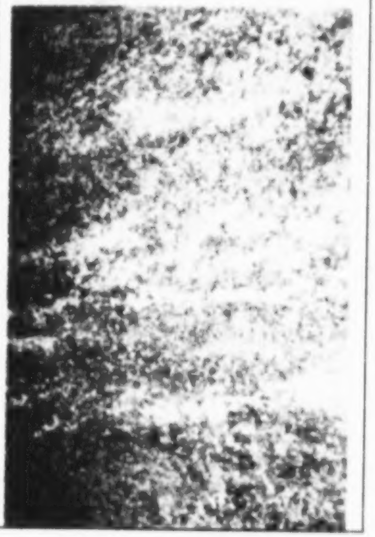
Circuit 1 – Airport 3	
Surface 1 – 	Surface 2 – 

Circuit 1 – Airport 4		
Surface 1 – 	Surface 2 – 	Surface 3 –

Circuit 1 – Airport 5		
Surface 1 - 	Surface 2 - 	Surface 3 - 
Surface 4 - 	Surface 5 - 	

Circuit 2 – Airport 1		
Surface 1 –	Surface 2 –	Surface 3 –
Circuit 2 – Airport 2		
Surface 1 –	Surface 2	

Circuit 2 – Airport 3	
Surface 1 – 	Surface 2 –
Circuit 2 – Airport 4	
Surface 1 – 	Surface 2–

Circuit 2 – Airport 5	
Surface 1 - 	Surface 2 - 

APPENDIX D

SUMMARY TEST DATA FOR THE ABS EFFECT TESTS

Table D.1: February 24 Tests

Test	Date	Surface	Vehicle / Time	ABS	Average Friction Coefficients For				Commments
No.				On/Off	Mk 2	Mk 3	Bomonk	Tapley	
1	24-Feb	Ice Lane A	Blazer 9:17	Off	0.123	0.108			Reference Run ABS Off Lanes A Test 1
1	24-Feb	Ice Lane B	Blazer 9:21	Off	0.120	0.106			Reference Run ABS Off Lanes B Test 1
1	24-Feb	Ice Lane C	Blazer 9:24	Off	0.120	0.112			Reference Run ABS Off Lanes C Test 1
2	24-Feb	Ice Lane A	Blazer 9:32	On	0.115	0.103			ABS On 2WD Lane A Test 2
3	24-Feb	Ice Lane A	Blazer 9:41	Off	0.119	0.103			ABS Off 2WD Test 3 Lane A
4	24-Feb	Ice Lane B	½-Ton 4x4 10:15	Off	0.112	0.106		0.135	ABS Off 2WD Test 4 Lane B
5	24-Feb	Ice Lane B	½-Ton 4x4 11:10	On	0.095	0.083		0.13	ABS On 2WD Test 5 Lane B
5A	24-Feb	Ice Lane B	½-Ton 4x4 11:15	On	0.092	0.082		0.127	ABS On 4WD Test 5A Lane B
6	24-Feb	Ice Lane C	¾-Ton 4x4 11:41	On	0.089	0.087			ABS On 2WD Test 6 Lane C
6A	24-Feb	Ice Lane C	¾-Ton 4x4 11:51	On	0.087	0.089			ABS On 4WD Test 6A Lane C
7	24-Feb	Ice Lane C	¾-Ton 4x4 12:00	Off	0.100	0.091			ABS Off 2WD Test 7 Lane C
51	24-Feb	¼ in. Loose Snow On Pavement	½-Ton 4x4 13:39	On		0.386			ABS On 2WD Test 51 East of centre line
52	24-Feb	¼ in. Loose Snow On Pavement	½-Ton 4x4 13:45	On	0.384	0.376			ABS On 2WD Test 52 East of centre line
53	24-Feb	¼ in. Loose Snow On Pavement	½-Ton 4x4 13:52	On	0.379	0.375			ABS On 4WD Test 53 East of centre line
54	24-Feb	¼ in. Loose Snow On Pavement	½-Ton 4x4 14:00	Off	0.272	0.263			ABS Off 2WD Test 54 East of centre line
55	24-Feb	¼ in. Loose Snow On Pavement	Blazer 14:15	On	0.244	0.230			ABS On 2WD Test 55 West of centre line
56	24-Feb	¼ in. Loose Snow On Pavement	Blazer 14:23	Off	0.257	0.249			ABS Off 2WD Test 56 West of centre line
57	24-Feb	¼ in. Loose Snow On Pavement	¾-Ton 4x4 15:01	On	0.342	0.329			ABS On 2WD Test 57 West of centre line
58	24-Feb	¼ in. Loose Snow On Pavement	¾-Ton 4x4 15:09	On	0.331	0.319			ABS On 4WD Test 58 West of centre line
59	24-Feb	¼ in. Loose Snow On Pavement	¾-Ton 4x4 15:16	Off	0.243	0.229			ABS Off 2WD Test 59 West of centre line
60	24-Feb	¼ in. Loose Snow On Pavement	¾-Ton 4x4 15:21	Off	0.242	0.223			ABS Off 4WD Test 60 West of centre line
61	24-Feb	¼ in. Loose Snow On Pavement	1-Ton 4x4 15:38	On	0.189	0.179			ABS On 2WD Test 61 East of centre line
62	24-Feb	¼ in. Loose Snow On Pavement	1-Ton 4x4 15:47	Off	0.213	0.205			ABS Off 2WD Test 62 East of centre
63	24-Feb	¼ in. Loose Snow On Pavement	FWD Car 16:03	On	0.345	0.331			ABS On Test 63 West of centre line
64	24-Feb	¼ in. Loose Snow On Pavement	½-Ton 2x4 16:05 Staff 21	Off	0.302				ABS Off Test 64 1st 5 east 2nd 5 west
65	24-Feb	¼ in. Loose Snow On Pavement	FWD Car 16:13	Off	0.309	0.298			ABS Off Test 65 West of centre line
66	24-Feb	3/8 in. Loose Snow On Pavement	RWD Car 16:51	On	0.291	0.284			ABS On Test 66 East of centre line
67	24-Feb	3/8 in. Loose Snow On Pavement	RWD Car 17:02	Off	0.293	0.283			ABS Off Test 67 East of centre line
68	24-Feb	3/8 in. Loose Snow On Pavement	Blazer 17:13	On	0.218	0.207			ABS On 2WD Test 68 1st 5 east 2nd 5 west
69	24-Feb	3/8 in. Loose Snow On Pavement	Blazer 17:18	Off	0.266	0.253			ABS Off 4WD Test 69 1st 5 east 2nd 5 west

Table D.2: February 25 Tests

Date	Surface	Vehicle / Time	ABS	Average Friction Coefficients For				Commments
			On/Off	Mk 2	Mk 3	Bomonk	Tapley	
25-Feb	1/8 in. Loose Snow on Pavement - Plowed Not Swept	Blazer 8:49	On	0.316	0.297			ABS On 2WD Test 70 East of centre line
25-Feb	1/8 in. Loose Snow on Pavement - Plowed Not Swept	Blazer 8:57	Off	0.299	0.283			ABS Off 2WD Test 71 East of centre line
25-Feb	1/8 in. Loose Snow on Pavement - Plowed Not Swept	½-Ton 4x4 9:11	On	0.390	0.366			ABS On 2WD Test 72 West of centre line
25-Feb	1/8 in. Loose Snow on Pavement - Plowed Not Swept	½-Ton 4x4 9:19	On	0.381	0.371			ABS On 2WD Test 73 West of centre line
25-Feb	1/8 in. Loose Snow on Pavement - Plowed Not Swept	½-Ton 4x4 9:27	Off	0.313	0.303			ABS Off 2WD Test 74 West of centre line
25-Feb	1/8 in. Loose Snow on Pavement - Plowed Not Swept	¾-Ton 4x4 9:43	On	0.303	0.295			ABS On 2WD Test 75 East of centre line
25-Feb	1/8 in. Loose Snow on Pavement - Plowed Not Swept	¾-Ton 4x4 9:53	Off	0.254	0.245			ABS Off 2WD Test 76 East of centre line
25-Feb	1/8 in. Loose Snow on Pavement - Plowed Not Swept	Blazer 10:32	Off	0.290	0.289	0.279	0.349	ABS Off 2 WD Test 77 West of centre line
25-Feb	1/8 in. Loose Snow on Pavement - Plowed Not Swept	Blazer 10:45	On	0.299	0.290	0.215	0.361	ABS On 2 WD Test 78 West of centre line
25-Feb	1/8 in. Loose Snow on Pavement - Plowed Not Swept	1-Ton 4x4 11:10	On	0.227	0.212	0.206	0.283	ABS On 2WD Test 78A East of centre line
25-Feb	1/8 in. Loose Snow on Pavement - Plowed Not Swept	1-Ton 4x4 11:25	Off	0.243	0.228	0.215		ABS Off 2WD Test 79 East of centre line
25-Feb	1/8 in. Loose Snow on Pavement - Plowed Not Swept	½-Ton 2x4 11:36	On	0.293		0.272		ABS On Staff 21 Test 80 west of centre line
25-Feb	1/8 in. Loose Snow on Pavement - Plowed Not Swept	½-Ton 2x4 11:45	Off	0.316		0.326		ABS Off Staff 21 Test 81 West of centre
25-Feb	1/8 in. Partly Compacted Snow on Pavement - note 1	Blazer 13:25	Off	0.375	0.381	0.361	0.473	ABS Off 2WD Test 82 West of centre line
25-Feb	1/8 in. Partly Compacted Snow on Pavement - note 1	Blazer 13:37	On	0.332	0.331	0.345	0.437	ABS On 2WD Test 83 West of centre line
25-Feb	1/8 in. Partly Compacted Snow on Pavement - note 1	½-Ton 4x4 13:59	On	0.353	0.383	0.339	0.459	ABS On 2WD Test 84 East of centre line
25-Feb	1/8 in. Partly Compacted Snow on Pavement - note 1	½-Ton 4x4 14:09	Off	0.388	0.376	0.265	0.443	ABS Off 2WD Test 85 East of centre line
25-Feb	1/8 in. Partly Compacted Snow on Pavement - note 1	¾-Ton 4x4 14:28	Off	0.421	0.394	0.336	0.469	ABS Off 2WD Test 86 West of centre line
25-Feb	1/8 in. Partly Compacted Snow on Pavement - note 1	¾-Ton 4x4 14:38	On	0.427	0.418	0.369	0.479	ABS On 2WD Test 86A West of centre line
25-Feb	1/8 in. Partly Compacted Snow on Pavement - note 1	FWD Car 14:52	On	0.468	0.470	0.417	0.528	ABS On Test 87 East of centre Wind scoured
25-Feb	1/8 in. Partly Compacted Snow on Pavement - note 1	FWD Car 15:01	Off	0.465	0.465	0.401	0.511	ABS Off Test 88 East of centre
25-Feb	1/8 in. Partly Compacted Snow on Pavement - note 1	RWD Car 15:43	Off	0.474	0.467	0.413	0.531	ABS Off Test 89 West of centre
25-Feb	1/8 in. Partly Compacted Snow on Pavement - note 1	RWD Car 15:53	On	0.410	0.406	0.369	0.484	ABS On Test 90 West side of centre
25-Feb	1/8 in. Partly Compacted Snow on Pavement - note 1	1-Ton 4x4 16:09	On	0.395	0.397			ABS On 2WD Test 91 East of centre line
25-Feb	1/8 in. Partly Compacted Snow on Pavement - note 1	1-Ton 4x4 16:17	Off	0.427	0.417			ABS Off Test 92 East of centre
25-Feb	1/8 in. Partly Compacted Snow on Pavement - note 1	Blazer 16:29	Off	0.438	0.426	0.466		ABS Off 2WD Test 93 East of centre.
								Surface snow/sand wind scoured
25-Feb	1/8 in. Partly Compacted Snow on Pavement - note 1	Blazer 16:36	Off	0.463	0.449	0.452		ABS Off 2WD Test 94 West of centre.
								Surface snow/sand wind scoured

1. This surface was 1/8 in. snow that had been partly compacted by traffic on pavement. It had been plowed but not swept, and sanded twice.

Table D.3: February 26 Tests

Test No.	Date	Surface	Vehicle / Time	ABS	Average Friction Coefficients For:				Comments
				On/Off	Mk 2	Mk 3	Bowmonk	Tapley	
10	26-Feb	Ice Lane A B C	Blazer 10:09	Off	0.129	0.125	0.140	0.182	ABS Off 4WD Test 10
									Stop 1-5 Lane A, 6-10 Lane B, 11-15 Lane C
11	26-Feb	Ice Lane A	FWD Car 10:38	On	0.171	0.169			ABS On Test 11 Lane A
12	26-Feb	Ice Lane A	FWD Car 10:48	Off	0.131	0.147			ABS Off Test 12 Lane A
13	26-Feb	Ice Lane C	RWD Car 11:05	Off	0.129	0.108			ABS Off Test 13 Lane C
14	26-Feb	Ice Lane C	RWD Car 11:16	On	0.122	0.103			ABS On Test 14 Lane C Questionable ABS
15	26-Feb	Ice Lane B	½-Ton 4x4 11:34 Windsor OPS	Off		0.127			ABS Off Test 15 YQB Lane B Decel #180
16	26-Feb	Ice Lane B	1-Ton 4x4 12:06	On	0.126	0.121			ABS On Test 16 Lane B
17	26-Feb	Ice Lane B	1-Ton 4x4 12:14	Off	0.110	0.100			ABS Off Test 17 2 WD Lane B
18	26-Feb	Ice Lane B	½-Ton 4x4 14:32 Windsor OPS	On		0.125			ABS On Test 18 2WD YQG Lane B
19	26-Feb	Ice Lane A B C	Blazer 14:40	Off	0.116	0.107			ABS Off Test 19 4WD
									Stop 1-5 Lane A 6-10 Lane B 11-15 Lane C
20	26-Feb	¼ in. Loose Snow On Compact Snow	Blazer 14:55	Off	0.316	0.293	0.320	0.365	ABS Off Test 20 4 WD
									Stop 1-5 Lane D 6-10 Lane E 11-15 Lane F
21	26-Feb	¼ in. Loose Snow On Compact Snow	Blazer 15:13	Off	0.293	0.281			ABS Off Lane D Test 21
22	26-Feb	¼ in. Loose Snow On Compact Snow	Blazer 15:20	On	0.259	2.030			ABS On Lane D Test 22
23	26-Feb	¼ in. Loose Snow On Compact Snow	½-Ton 4x4 15:35	On	0.313	0.315	0.341	0.385	ABS On 2WD Test 23 Lane E
									Rutting on Packed/Compact Snow Lane E
24	26-Feb	¼ in. Loose Snow On Compact Snow	½-Ton 4x4 15:45	Off	0.343	0.331	0.359	0.412	ABS Off Test 24 2WD Lane E
									Rutting on Compact/Packed Snow Lane E
25	26-Feb	¼ in. Loose Snow On Compact Snow	¾-Ton 4x4 16:25	Off	0.250	0.223			ABS Off Test 25 2WD Lane F
									Firm Compact Snow Base Lane F
26	26-Feb	¼ in. Loose Snow On Compact Snow	¾-Ton 4x4 16:12	On	0.255	0.227			ABS On Test 26 2WD Lane F
									Firm Compact Snow Base Lane F
26A	26-Feb	¼ in. Loose Snow On Compact Snow	½-Ton 4x4 16:22 Windsor OPS	On		0.209			ABS On Test 26A 2WD Lane F YQG
27	26-Feb	¼ in. Loose Snow On Compact Snow	½-Ton 4x4 16:27 Windsor OPS	Off		0.190			ABS Off Test 27 2WD Lane F YQG
28	26-Feb	¼ in. Loose Snow On Compact Snow	FWD Car 17:03	On	0.332	0.311	0.319	0.362	ABS On Test 28 Lane D E F
									Stop 1-5 Lane D 6-10 Lane E 11-15 Lane F
29	26-Feb	¼ in. Loose Snow On Compact Snow	FWD Car 17:11	Off	0.247	0.333	0.335	0.381	ABS Off Test 29 Lane D E F
									Stop 1-5 Lane D 6-10 Lane E 11-15 Lane F
30	26-Feb	¼ in. Loose Snow On Compact Snow	RWD Car 17:23	On	0.255	0.244			ABS On Test 30 Lane D E F
									Stop 1-5 Lane D 6-10 Lane E 11-15 Lane F
31	26-Feb	¼ in. Loose Snow On Compact Snow	RWD Car 17:31	Off	0.257	0.355			ABS Off Test 31 Lane D E F
									Stop 1-5 Lane D 6-10 Lane E 11-15 Lane F
32	26-Feb	¼ in. Loose Snow On Compact Snow	Blazer 17:43	Off	0.247	0.250			ABS Off Test 32 4WD Lane D E F
									Stop 1-5 Lane D 6-10 Lane E 11-15 Lane F

Table D.4: February 27 Tests

Test No.	Date	Surface	Vehicle / Time	ABS	Average Friction Coefficients For:				Comments
				On/Off	Mk 2	Mk 3	Bowmonk	Tapley	
40	27-Feb	¼ in. Loose Snow On Pavement	Blazer 09:47	Off	0.364	0.362			ABS Off Test 40 4WD
41	27-Feb	¼ in. Loose Snow On Pavement	Blazer 9:55	On	0.3	0.294			ABS On Test 41 2WD
42	27-Feb	¼ in. Loose Snow On Compact Snow	Blazer 10:01	Off	0.256	0.236			ABS Off 4WD Lane F Test 42
									Firm Compact Snow Base Lane F Only
43	27-Feb	¼ in. Loose Snow On Compact Snow	Blazer 10:08	On	0.307	0.297			ABS On 2WD Lane F Test 43
44	27-Feb	¼ in. Loose Snow On Pavement	½-Ton 4x4 10:40	On	0.410	0.396			ABS On Test 44 2WD
45	27-Feb	¼ in. Loose Snow On Pavement	½-Ton 4x4 10:43	Off	0.360	0.348			ABS Off Test 45 4WD
46	27-Feb	¼ in. Loose Snow On Compact Snow	½-Ton 4x4 10:50	Off	0.246	0.236			ABS Off 4WD Lane F Test 46
46A	27-Feb	¼ in. Loose Snow On Compact Snow	½-Ton 4x4 10:57	On	0.259	0.239			ABS On 2WD Lane F Test 46A
47	27-Feb	¼ in. Loose Snow On Pavement	¾-Ton 4x4 11:18	On	0.364	0.370			ABS On Test 47 2WD
47A	27-Feb	¼ in. Loose Snow On Pavement	¾-Ton 4x4 11:22	Off	0.312	0.314			ABS Off Test 47A 2WD
48	27-Feb	¼ in. Loose Snow On Compact Snow	¾-Ton 4x4 11:30	Off	0.219	0.219			ABS Off 2WD Test 48 Lane F
									Glazing Evident on Lane F
49	27-Feb	¼ in. Loose Snow On Compact Snow	¾-Ton 4x4 11:41	On	0.208	0.203			ABS On Test 49 2WD Lane F
									Glazing Evident on Lane F

BMT Fleet Technology Limited is a member of British Maritime Technology, a leading multi-disciplinary engineering and technology consultancy. BMT Fleet Technology Limited's mission is to provide practical solutions to engineering problems and advances in technical knowledge through high quality applied research, experimentation, design and engineering analysis.

BMT Fleet Technology Limited
311 Legget Drive, Kanata, Ontario Canada K2K 1Z8
Tel: (613) 592-2830 Fax: (613) 592-4950 E-mail: fleet@fleetech.com
Website: www.fleetech.com